machine design

BY ENGINEERS FOR ENGINEERS

CAN FEA TEST SPORTS GEAR? p. 60

PRACTICAL TIPS FOR SPECIFYING SENSORS p. 66

DIFFERENCES BETWEEN MOTORS FOR MOTION p. 74

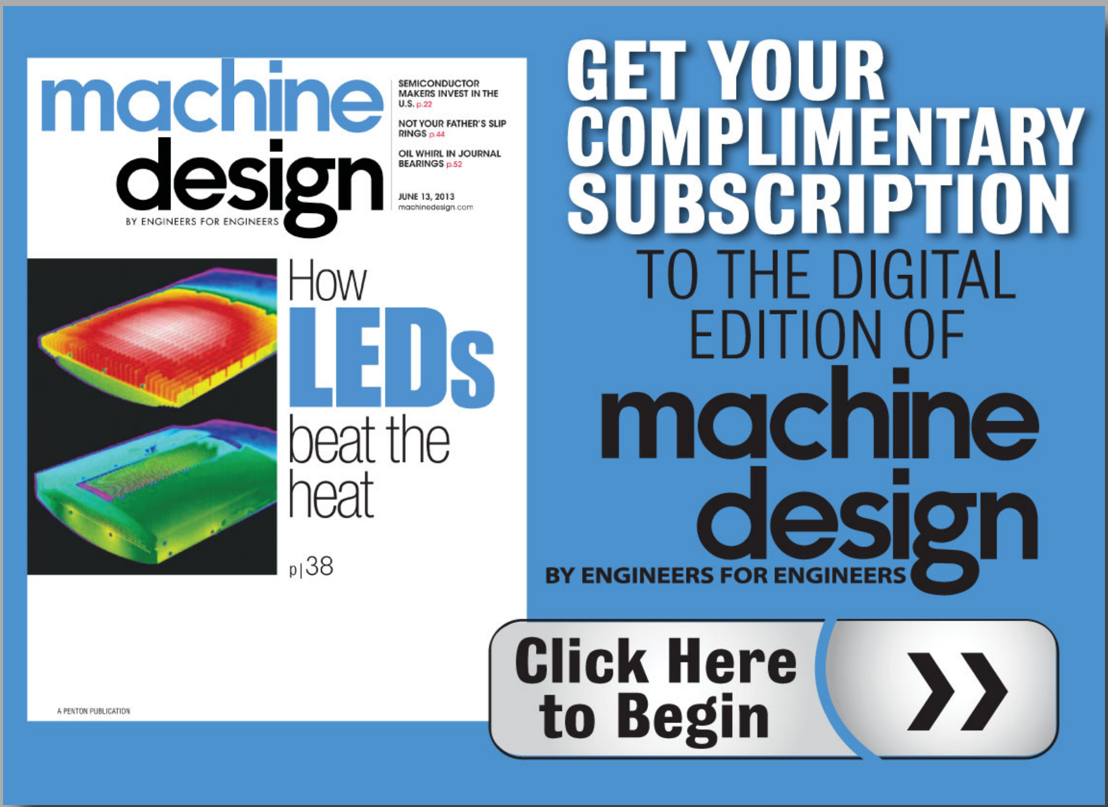
MAY 2015

machinedesign.com

HYDRAULIC DIRECT DRIVES:

Heavy Lift Power

p|38



machine design
BY ENGINEERS FOR ENGINEERS
SEMICONDUCTOR MAKERS INVEST IN THE U.S. p.22
NOT YOUR FATHER'S SLIP RINGS p.44
OIL WHIRL IN JOURNAL BEARINGS p.52
JUNE 13, 2013
machinedesign.com
How LEDs beat the heat
p|38
A PENTON PUBLICATION
GET YOUR COMPLIMENTARY SUBSCRIPTION
TO THE DIGITAL EDITION OF
machine design
BY ENGINEERS FOR ENGINEERS
Click Here to Begin

BAD WEATHER AHEAD
WHY WAIT before it's too late?
Battery Based
No Battery
Don't Wait - we offer 2 Unique Solutions
All-In-One DC-UPS
• Power supply, battery charger, battery care module and backup module in one device
• Three charging modes
• Available in 12VDC, 24VDC and 48VDC
• Adjustable charging current up to 35A
• Easy battery diagnosis and fault identification either by LED or external devices connected to fault
• High efficiency up to 91% via switching technology
Ultra Capacitor DC-UPS
• Environmentally safe
• No toxic chemicals
• Virtually maintenance free
• Operating temperature range -40°C to +65°C
• Higher energy vs. electrolytic capacitors
• 12 or 24V system design
• Up to 10,000 Ws energy plus extension modules
• Customized systems up to 600A available
• Higher power vs. batteries
• Resists shock and vibration
Altech Carries a Full Line of DIN Rail Power Supplies
Wide Power Range (10W-960W)
UL508 Listed and/or UL60950-1 recognized
Class 2, UL1310 recognized
Altech Corp.®
Contact Altech today.
908.806.9400
www.altechcorp.com/power

MAY 2015 | VOLUME 87, ISSUE 5

machine design

In This Issue

FEATURES

38 INDUSTRIAL WORKHORSE: LARGE HYDRAULIC DIRECT DRIVES
Key features, functions, and application considerations for large hydraulic material-handling systems.

48 FIVE HEAVY-DUTY GANTRY ALTERNATIVES
Save time and money with these five highly configurable products that can be used in linear-motion-guided gantry configurations for factory-floor automation in place of high-cost multi-axis robots.

60 CAN FEA TEST SPORTS GEAR?
Researchers examine whether FEA can replace field testing for golf balls and other sports gear.

66 PRACTICAL TIPS FOR SPECIFYING SENSORS
Experts in the industry talk about common concerns when considering sensors.

74 DIFFERENCES BETWEEN MOTORS FOR MOTION
Several differentiating factors influence the choice of motor for robotics, medical, packaging, and other motion-control applications.

38

48

NEWS

16 ECOCAR 3 CHALLENGES STUDENTS, INDUSTRY PARTNERS TO IMPROVE HYBRID CARS

COLUMNS

8 EDITORIAL
Engineering: The Key to Untold Riches? — Stephen Mraz

32 INTERVIEW
Is Additive Manufacturing Moving into Your Home? — Bram de Zwart

112 PRODUCT DEVELOPMENT
Maximizing Revenues from the New Product Pipeline — Bradford L. Goldense

DISTRIBUTION RESOURCE

78 ELECTROMECHANICAL SOLUTIONS IMPROVE
78 GLOBAL PURCHASING'S 2015 TOP 50
82 EDS FEATURES CELEBRITY ENGINEER GRANT IMAHARA

DEPARTMENTS

4 ON MACHINEDESIGN.COM
10 LETTERS
12 WHAT'S INSIDE
Heavy-Duty Caster Carries 50-Ton Loads

Inductive Linear Position Sensor Handles Off-Road Challenges and Automation

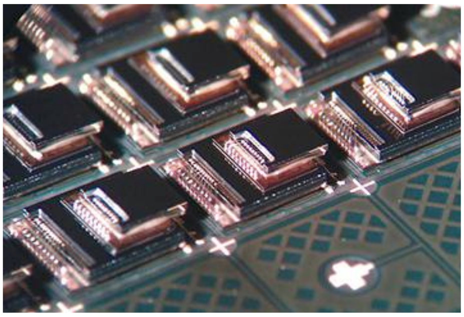
28 ENGINEERING ESSENTIALS
Why Interlock Guards Trump Lockout/Tagout

88 WHAT'S THE DIFFERENCE?

PRODUCTS

98 NEW PRODUCTS
108 LITERATURE EXPRESS
110 DATA FILES
111 CLASSIFIEDS
111 AD INDEX

60



66

ON THE COVER: The newest hydraulic direct drives combine smaller sizes, lighter weight, and much higher power density.

JOIN US ONLINE

twitter.com/machinedesign

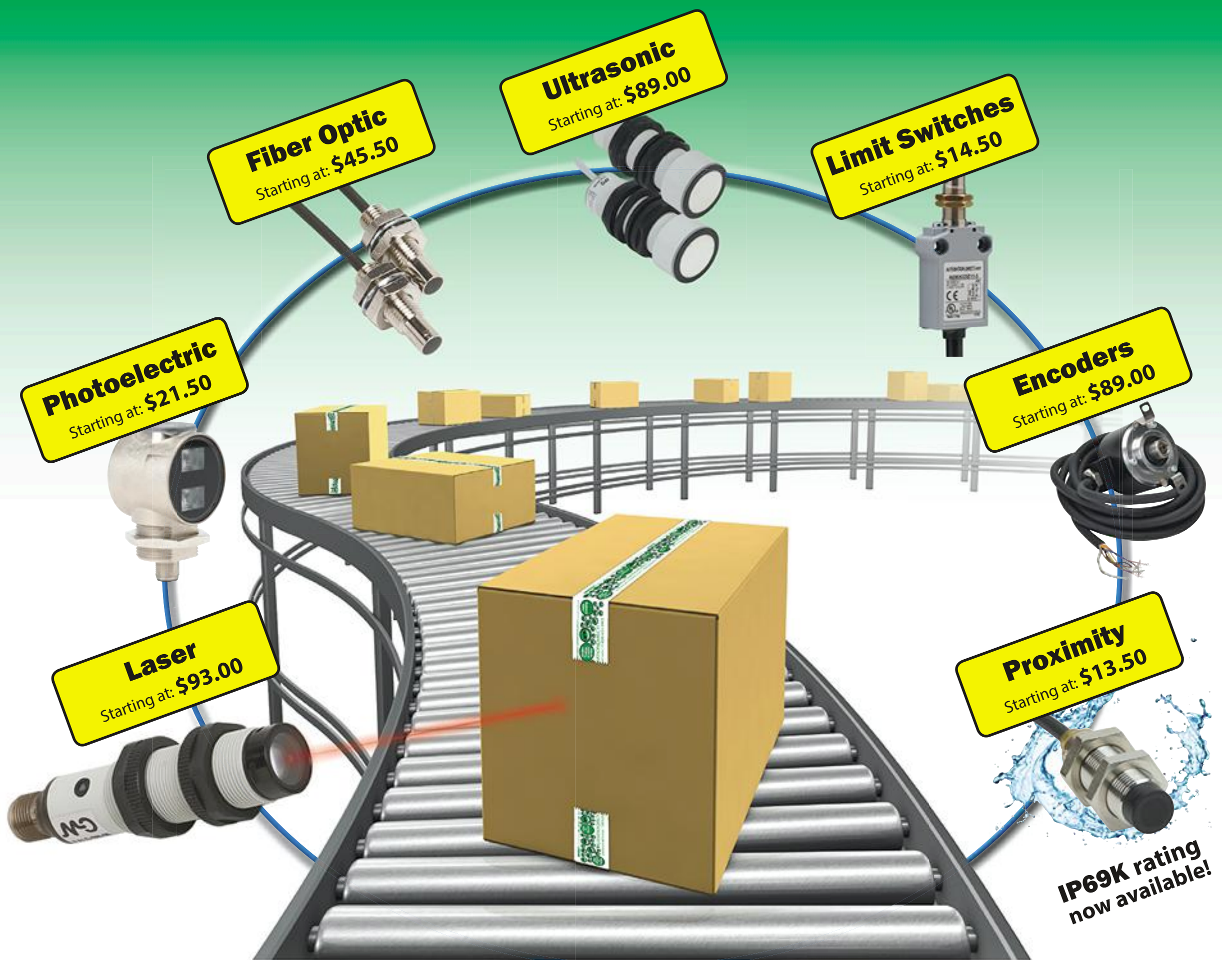
facebook.com/MachineDesignMagazine

 MACHINE DESIGN (ISSN 0024-9114) is published monthly by Penton Media, Inc., 9800 Metcalf Ave., Overland Park, KS 66212.
Paid subscriptions include issues 1-12. Rates: U.S.: $139/year; $199/two years. Canada/Mexico: $159/year; $239/two years; All other countries: $199/year; $299/two years. Cost for back issues are U.S. $10.00 per copy plus tax, Canada $15.00 per issue plus tax, and Int'l $20.00 per issue. OEM Handbook and Supplier Directory, $50.00 plus tax. Prepaid subscription: Penton Media (MACHINE DESIGN), P.O. Box 2100, Skokie IL 60076-7800. Periodicals postage paid at Kansas City, MO and additional mailing offices.

Can GST #R126431964. Canadian Post Publications Mail Agreement No.40612608. Canada return address: IMEX Global Solutions, P.O. Box 25542, London, Ont., N6C 6B2.
Digital subscription rates: U.S.: $69/year. Canada/Mexico: $79/year. All other countries: $99/year. Print/Digital combo subscription rates: U.S.: $174/year; $249/two years. Canada/Mexico: $199/year; $299/two years; All other countries: $249/year; $374/two years.
POSTMASTER: Send change of address notice to Customer Service, MACHINE DESIGN, P.O. Box 2100, Skokie, IL 60076-7800.

The SENSORS you need...

at the prices you want!



Infrared, Fiber Optic, Magnetic, Laser, Ultrasonic... it's all here!

AutomationDirect offers a wide variety of sensors, encoders and limit switches to give reliable and accurate discrete data for any application. From position tracking and object detection to motion monitoring and control, we are your one-stop shop for sensors.

- Inductive Proximity Sensors (metallic materials) (starting at $13.50, IP69K-rated starting at $18.75)
- Capacitive Proximity Sensors (starting at $59.00)
- Magnetic Proximity Sensors (starting at $44.50)
- Ultrasonic Sensors (transparent materials) (starting at $89.00)
- Fiber Optic Sensors (starting at $45.50)
- Laser Sensors (diffuse laser sensors start at $93.00)
- Photoelectric Sensors (starting at $21.50)
- Incremental and Absolute Encoders (optical rotary encoders start at $89.00)
- Limit Switches (starting at $14.50)

Also Available

Temperature Sensors

Level Sensors

Pressure Sensors

Research, price, buy at:
www.automationdirect.com/sensors

Order Today, Ships Today!

VOTED #1 Best in SERVICE 14 YEARS 2001 - 2014

AUTOMATIONDIRECT.com
1-800-633-0405
the #1 value in automation

onmachinedesign.com

GALLERY:

STEALTH VEHICLES

http://machinedesign.com/defense/8-stealthy-military-vehicles#slide-0-field_images-48121

By the 1970s, engineers had discovered how to build structures that were difficult, if not impossible, to see on radar. Then in 1978, the United States started building stealthy military vehicles that would be invisible to enemy radars. Check out this collection of “under-the-radar” military might.

VIDEO:

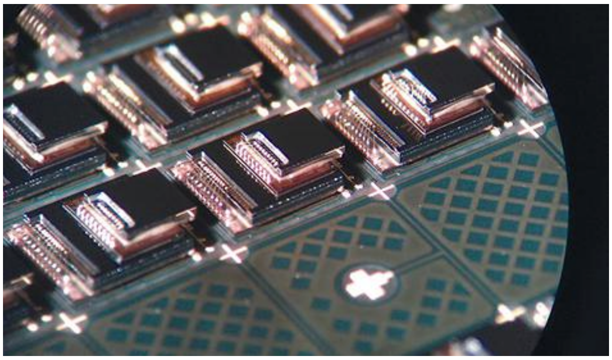
SCANNING DEVICE TAKES 3D MEASUREMENTS

http://machinedesign.com/cad/scanning-device-takes-3d-measurements

The portable HandySCAN 3D 300 and 700 models can generate 3D measurements of scanned objects at resolutions of 0.1 and 0.05 mm, respectively. Working at speeds 25 times faster than the previous generation, HandySCAN produces data with an accuracy of up to 0.04 mm. Check out the video online.

join us online

twitter.com/machinedesign facebook.com/MachineDesignMagazine



THE FUTURE OF CARBON FIBER

http://machinedesign.com/blog/8-myths-about-rd-tax-credit

Carbon-fiber composites (also called carbon-fiber reinforced plastics or CFRPs) are finding their way into new applications as industries demand materials with ever-higher strength-to-weight ratios, corrosion resistance, and workability.

5 MYTHS ABOUT USB FLASH DRIVES

http://machinedesign.com/blog/5-myths-surrounding-usb-flash-drives

Can magnets erase content from a USB drive? What if a USB gets wet? Experts at Premium USB take the time to dispel some of the myths and fallacies that have sprung up around the ubiquitous USB.

machine design

MAY 2015

EDITORIAL

EXECUTIVE EDITOR: **KENNETH J. KORANE** ken.korane@penton.com
SENIOR EDITOR: **STEPHEN J. MRAZ** stephen.mraz@penton.com
TECHNOLOGY EDITOR: **CARLOS GONZALEZ** carlos.gonzalez@penton.com
TECHNOLOGY EDITOR: **JEFF KERNS** jeff.kerns@penton.com

CONTENT PRODUCTION DIRECTOR: **MICHAEL BROWNE** michael.browne@penton.com
CONTENT PRODUCTION SPECIALIST: **ROGER ENGELKE** roger.engelke@penton.com
PRODUCTION EDITOR: **JEREMY COHEN** jeremy.cohen@penton.com
ASSOCIATE CONTENT PRODUCER: **ILIZA SOKOL** iliza.sokol@penton.com
ASSOCIATE CONTENT PRODUCER: **LEAH SCULLY** leah.scully@penton.com

INDUSTRY COVERAGE:

FASTENING & JOINING, PACKAGING, MANUFACTURING: **STEPHEN J. MRAZ**
FLUID POWER, MECHANICAL: **KENNETH J. KORANE**
MOTION CONTROL, CAD/CAM: **CARLOS GONZALEZ**
3D PRINTING, MATERIALS, ELECTRONICS/ELECTRICAL: **JEFF KERNS**

ART DEPARTMENT

ART DIRECTOR: **RANDALL L. RUBENKING** randall.rubenking@penton.com
GROUP DESIGN DIRECTOR: **ANTHONY VITOLO** tony.vitolo@penton.com
SENIOR ARTIST: **JIM MILLER** jim.miller@penton.com

PRODUCTION

GROUP PRODUCTION DIRECTOR: **CAREY SWEETEN** carey.sweeten@penton.com
AD OPERATIONS SPECIALIST: **BRENDA WILEY** brenda.wiley@penton.com

AUDIENCE MARKETING

USER MARKETING DIRECTOR: **BRENDA ROODE** brenda.roode@penton.com
USER MARKETING MANAGER: **DEBBIE BRADY** debbie.brady@penton.com
FREE SUBSCRIPTION/STATUS OF SUBSCRIPTION/ADDRESS CHANGE/MISSING BACK ISSUES:
HALLMARK DATA **T** | 847.763.9670 **F** | 847.763.9673 machinedesign@halldata.com

ONLINE

PRODUCT DEVELOPMENT DIRECTOR: **RYAN MALEC** ryan.malec@penton.com
CLIENT SERVICES MANAGER: **JOANN MARTIN** joann.martin@penton.com

SALES & MARKETING

MANAGING DIRECTOR: **TRACY SMITH** **T** | 913.967.1324 **F** | 913.514.6881 tracy.smith@penton.com

REGIONAL SALES REPRESENTATIVES
AK, AZ, CA, CO, HI, ID, IA, KY, MN, MT, ND, NE, NV, OR, SD, TN, UT, WA, WI, WY, WESTERN CANADA:
PAUL MILNAMOW paul.milnamow@penton.com **T** | 312.840.8462 **F** | 913.514.3957
DC, DE, MD, NC, NJ, NY, OH, PA, SC, VA, WV:
BRANDY BISSELL brandy.bissell@penton.com **T** | 234.678.8401 **F** | 913.514.6357
CT, MA, ME, NH, RI, VT, EASTERN CANADA:
LIZ STOTT, liz.stott@penton.com **T** | 857.636.9737 **F** | 913.514.6914
IL, IN, MI, CENTRAL CANADA:
MARTY McCLELLAN marty.mcclellan@penton.com **T** | 312.840.8488 **M** | 312.343.9278
AL, AR, FL, GA, KS, LA, MO, MS, NC, NM, OK, SC, TX:
CARRIE HALBROOK carrie.halbrook@penton.com **T** | 317.358.9965 **F** | 913.514.3965

INTERNATIONAL SALES REPRESENTATIVES
BELGIUM, FRANCE, LUXEMBURG, NETHERLANDS, PORTUGAL, SCANDINAVIA, SPAIN, UNITED KINGDOM: **STUART PAYNE**
stuart.payne@husonmedia.com **T** | 011.44.1625.876622 **M** | 011.44.7794.366887
GERMANY, AUSTRIA, AND SWITZERLAND: **CHRISTIAN HOELSCHER** christian.hoelscher@husonmedia.com
T | 011.49.89.95002778 **F** | 011.49.89.95002779
ITALY: **CESARE CASIRAGHI** cesare@casiraghi,info **T** | 011.390.31.261407 **F** | 011.390.31.261380
JAPAN, ASIA: **HELEN LAI** helen@twoway-com.com **T** | 866.2.2727.7799 **F** | 866.2.2727.3686

DESIGN ENGINEERING & SOURCING GROUP

VICE PRESIDENT & MARKET LEADER: **BILL BAUMANN**
GROUP DIRECTOR OF EDITORIAL CONTENT AND USER ENGAGEMENT: **NANCY FRIEDRICH**
GROUP DIRECTOR OF OPERATIONS: **CHRISTINA CAVANO**
GROUP DIRECTOR OF MARKETING: **JANE COOPER**

PENTON

CHIEF EXECUTIVE OFFICER: **DAVID KIESELSTEIN** david.kieselstein@penton.com
CHIEF FINANCIAL OFFICER: **NICOLA ALLAIS** nicola.allais@penton.com
SENIOR VP, DESIGN ENGINEERING GROUP: **BOB MACARTHUR** bob.macarthur@penton.com

1166 AVENUE OF THE AMERICAS, 10TH FLOOR
NEW YORK, NY 10036 **T** | 212.204.4200

Penton

Electronic Design | Machine Design | Microwaves & RF | Medical Design | Source ESB | Hydraulics & Pneumatics | Global Purchasing | Distribution Resource
Power Electronics | Defense Electronics | Electronic Design Europe | Engineering TV

Editorial

STEPHEN MRAZ | Senior Editor

Engineering: The Key to Untold Riches?

More people on the list of the world's 100 richest people hold engineering degrees than any other degree, according to a study by Approved Index, a business-to-business buying platform. Engineering grads make up a little more than 20% of that top 100 list and average $25.8 billion in wealth. In fact, the person at the top of the list, Carlos Slim, is also an engineer (a civil engineer) and he has amassed almost $50 billion.

The next most common college major for those on the list is finance, and about 10% of them have earned that degree. They "only" managed to accumulate $22.5 billion. It also seems odd that those without any college degrees average $24 billion in wealth, $1.5 billion more than those who studied finance.

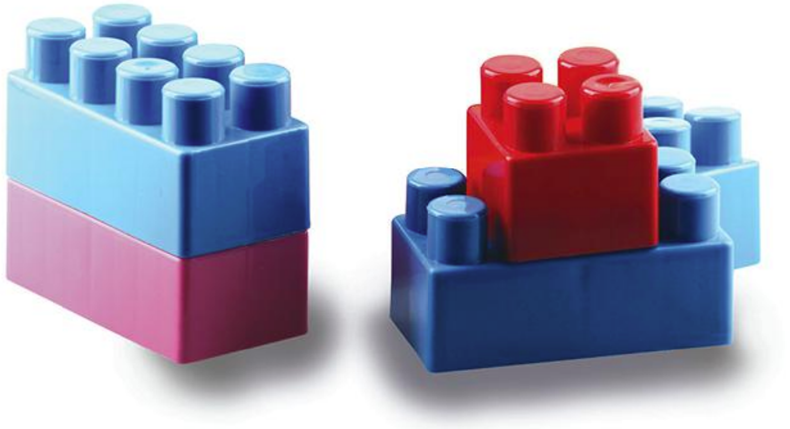
These statistics on an incredibly small portion of engineers and other professionals provide fine fodder for discussions after work or over lunch. But some media outlets, including CNBC and the UK's *Daily Mail* and *The Telegraph*, are using the statistics to urge more youngsters to pursue engineering degrees—as if the only thing standing between a high-school grad and a billion-dollar nest egg is an engineering degree.

It is inconceivable that any of those extremely well-off engineers who made it onto that list did so by working for Ford or even Apple as an engineer. Mr. Slim, for example, took his degree in civil engineering and immediately started his own brokerage firm, then went on to invest in construction, restaurants, and real estate.

I doubt any of those billionaire engineers reaped their windfalls from an invention or technological advancement. Like Mr. Slim, they more likely earned their wealth in the business of wheeling and dealing. Still, that's not to say their engineering education didn't play a role in their wealth-gathering activities.

There are few college disciplines better than engineering at giving a person a comprehensive background on the physical world, along with the mathematical skills and experience to analyze trends and other streams of data. It's a solid foundation for a host of careers outside engineering and intelligent employers know this. But it's not good choice if your overriding goal is to amass a fortune.

Hopefully, articles and studies like this will not fool gullible and naïve (and greedy) high-school juniors and seniors when they are choosing their college majors. But if they have the requisite aptitude and attitude for engineering, as well as a sincere interest in science and technology, it's a great choice. And although they probably won't end up billionaires, they will likely have a financially comfortable career.



STEM STARTER MEMORIES

The two toys that got me interested in engineering were the Erector Set and Tinker Toys. I loved to play with both, but the Erector Set was my favorite.

I also once tried to build a radio from a kit I received for Christmas. However, because I was only 8 or 10 years old and could not read a schematic, I tried to build it using a picture of the assembled radio, just by matching the components. Of course, not knowing how to read the values of the resistors, capacitors, and other components, I probably mixed them all up. Needless to say, it did not work. But, at least it did not smoke up or electrocute me.

Rich Abramczyk

I recall getting a 120-V electric train for Christmas at the age of about 7. My first instinct was to take the cover off the engine to see how fast it really could go. With another STEM starter, a model airplane, I remember choking on the fumes after I tried to soup it up and was testing it by running in a vise in my father's workshop. Many other episodes followed.

Mike Fraser

Of course, there were many different things that helped, entirely unconsciously, to lead me to where I am now. Tinker Toys, Erector Sets, Legos, and so on. But when I read your editorial inviting this feedback, the one that first popped into my mind was the Visible V8 engine model kit.

I checked it out on the Internet and downloaded an image of the box. Seeing it actually made me choke up. That was unexpected.

As a kid, I wondered how combustion engines worked. After a few hours, or probably days, of building this model, the principles of operation became crystal clear (unintended pun!). It was also relatively simple to extrapolate those principles to other types of internal combustion engines. Suddenly I had this intimate understanding of how engines worked and I became quite adept at fixing small engines on lawn mowers and mini bikes, and later motorcycles, cars, and trucks.

Tom Hennessey

My STEM starter was a building set called Robotix. I received a big box for Christmas, circa 1986. My father and I split the set and tried to create robots that could push the other off the coffee table. I never looked back.

Ben Hardy

I had several things that directed me toward an engineering-related field. The most influential ones were the Estes model rockets. I had several and I enjoyed making modifications, adding two motors to a rocket, adding larger and multiple parachutes, and so on. I would even make it a goal to not let the rocket hit the ground after I launched it. I would catch them out of the air even when fired with a C6-5 engine.

Nate Meyerhoffer

There is no question that the most exciting educational tool I had was the American Basic Science Club. It was a monthly kit devoted to some aspect of science and engineering. Each kit built on the previous one and there was tremendous ingenuity in how each let me use inexpensive materials to complete projects in optics, electronics, nuclear physics, chemistry, and so on. I can remember waiting in anticipation each month for the next package to arrive.

It is time for a replacement to arise.

Bob Johnson

One of my STEM starters was Things of Science, a subscription service that sent out a little blue box about once a month or so that had some sort of kit to do a science project, usually with some addition of common bits found around the home. A couple of kits that really stick in my mind were the electric motor (wire wrapped around nails, etc.) my father and I made, and a sextant (a paper pattern to paste on a piece of cardboard and some mirrors and other bits). I made it by myself, then my father, a merchant marine and naval officer, showed me how to use it to take a star sight. Obviously there was a lot of parental involvement in some of them, but that was a big part of the fun. I got my daughter a subscription in about 1989 or so, but it went under a couple of years later.

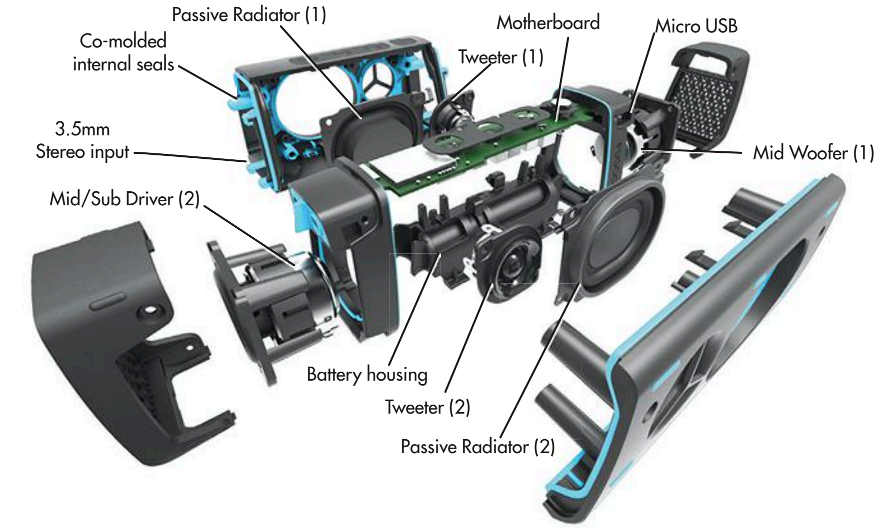
I occasionally talk to people about reviving this. Although I've gotten some interest, no one is quite sure of how to go about it. This is something various engineering societies could cooperate on and run if we could get enough enthusiasm going. Any comments you might have about it would be appreciated.

Chris

Speakers That Keep Playing and Playing

CEO GARY ELSASSER showed the Fugoo mobile speaker at this year's luxury show in New York City. When he wasn't busy taking advantage of its Ingress Protection rating of IP67 by throwing the FUGOO into a tank of water or on the floor, he told Machine Design what went into this speaker's development. This exploded view of the core slips into different protective jackets. Shown here is the six-speaker core, though in July 2015 Fugoo will be releasing the XL line featuring eight speakers.

Co-molded seals: These are throughout the FUGOO Core and give it full protection from water, dirt, dust, and mud. This seal also improves the sound quality and allows the speaker to withstand being submerged in up to 3.3 feet of water.



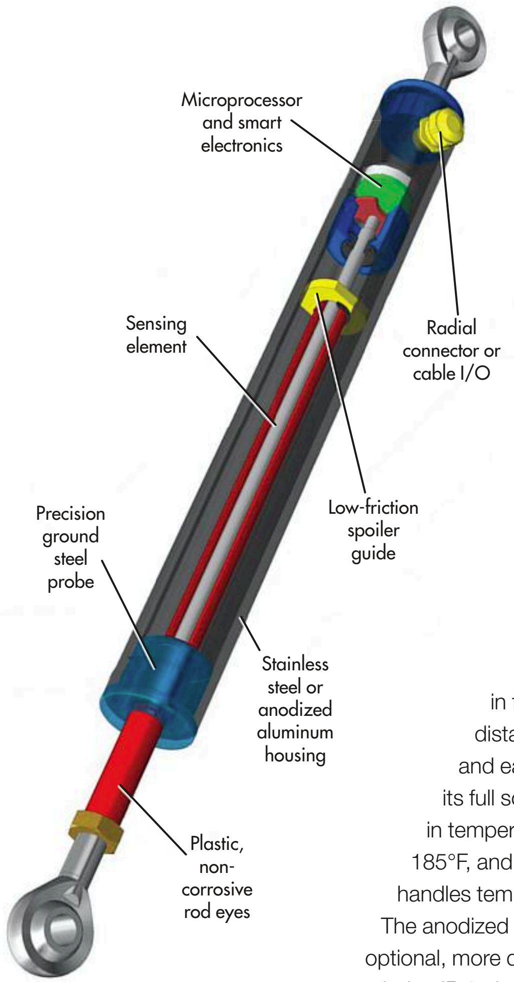
Electronics: The battery is a rechargeable lithium-ion that can play continuously for 40 hours and has efficiency to deliver 75% of performance after five years of use. FUGOO offers Wireless Bluetooth technology with IP67-certified 3.5 mm input jack and mini USB charging port, so no port covers are required for water immersion. It also offers a Digital Signal Processor that dynamically adjusts the sound ranges as the overall volume is adjusted. A built-in omnidirectional microphone gives this portable device full-duplex speakerphone functionality as well as Siri and Google Now voice control with a smartphone or tablet.

28mm neodymium tweeters (2): Magnetic ferrofluid in the tweeters creates a fluid, but physical connection between the speaker and the permanent neodymium magnet to use the magnet and surrounding structure as a heat sink. It also provides a slight damping effect on the voice coil to minimize unwanted acoustic resonance. Fugoo also has worldwide patents on the methods to deliver full 360-deg. sound with speakers on all sides of the product.

43 x 54mm passive radiators (2): The inclusion of two passive radiators allows listeners to get the most sound out of their speakers. It's a little-known fact that as much sound is generated from the back of the speaker as from the front. Passive radiators help take advantage of the full power of the speaker by adding a deep bass from the pressure behind the speakers.

39mm neodymium aluminum domed mid/woofer drivers (2): Two mid woofers give midrange sound to complete this portable sound system.

Inductive Linear Position Sensor Handles Off-Road Challenges

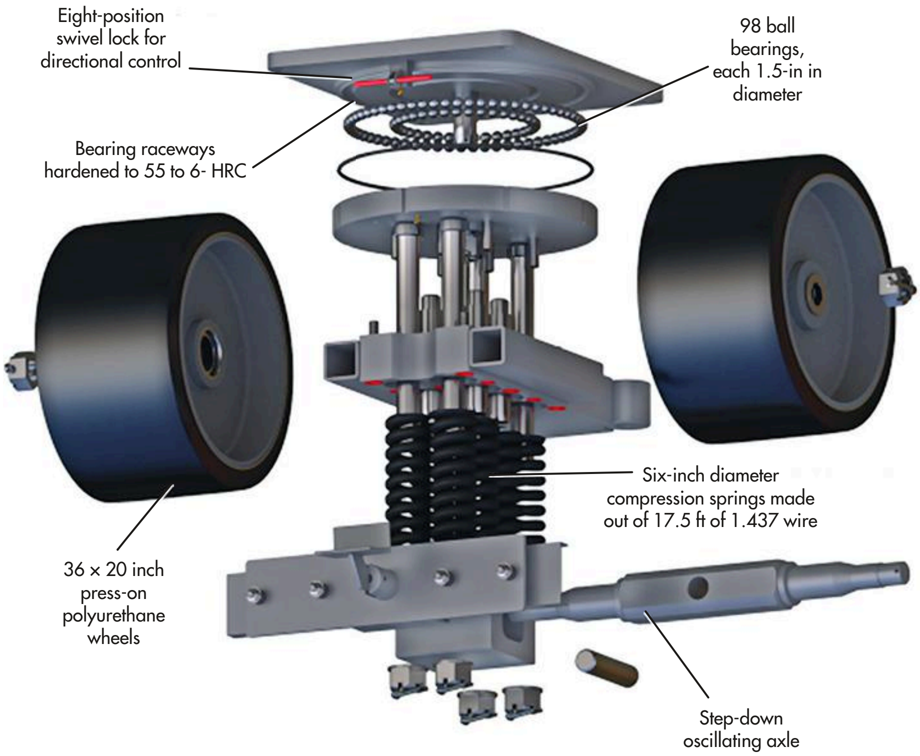


THE LR-72 SERIES of linear variable inductive transducers from the Alliance Sensor Group (alliancesensors.com), Moorestown, N.J., was designed to be rugged enough for use in off-road vehicles, show plows, and salt trucks, as well as other applications that expose them to harsh environments. This also makes the position sensors ideal for factory automation, material handling, and packaging equipment.

The sensors are available in five sizes and can measure distances ranging from 2 to 8 in., and each is accurate to 0.15% of its full scale output. They operate in temperatures ranging from -4 to 185°F, and an extended-range version handles temperatures from -40 to 221°F. The anodized aluminum housing and the optional, more durable, steel version are sealed to IP 67 levels. The sensors' contactless operation prevents wear from dithering or cycling. The sensors can also withstand 1,000 g of shock for 11 msec and 4.2 g of vibrations in the 2 to 2,000 Hz range. The sensor operates on a variety of DC voltages and offers users a choice from four analog outputs. They also include the manufacturer's SenSet field-calibration feature.

Heavy-Duty Caster Carries 50-Ton Loads

ENGINEERS AND TECHNICIANS at Hamilton Caster (www.hamiltoncaster.com), Hamilton, Ohio, recently designed and built four 100,000-lb capacity casters for a federal contractor. Fully assembled, each two-wheeled caster towers 4.3 ft. tall and weighs more than 8,000 lb. Casters have a spring-loaded suspension, an eight-position swivel lock for directional control, a 7-in.-diameter oscillating axle



to accommodate uneven surfaces, and a foot-operated brake. Hamilton had to use a CNC milling machine to cut two raceways into the mounting plate, one measuring 18-in. in diameter, the other 32 in. To increase wear resistance, both raceways were flame-hardened. The axle, spring pins, and spring block were precision-machined on a CNC lathe. To insert the spring pins into the spring block, Hamilton used dry ice to contract the steel by 0.003 in. to let the spring pins slide into the block.

News

EcoCAR 3 Challenges Students, Industry Partners to IMPROVE HYBRID CARS

The Global Vehicle Motor (GVM) line by Parker Hannifin has motors for a range of different automobiles and is compatible with electric drivetrains.

Students, you have a Chevy Malibu and three years to improve its efficiency and emission levels without compromising performance or safety. Focus on hybrid-electric technology. And… go.

This was the EcoCAR 2 challenge, presented by Argonne National Laboratory and accepted by students at 15 universities. For six straight years, Ohio State University's team has made the top five. This year, the race is on, as the OSU team intends to achieve its seventh victory in the EcoCAR 3 challenge.

EcoCAR 3, which started August 1, 2014 and terminates in 2018, is sponsored by General Motors and the U.S. Department of Energy. The new challenge features the most technologically advanced Camaro and tasks the team with creating an energy-efficient powertrain to maximize performance. The students' focus is on choosing alternate fuels and advanced technologies to lower greenhouse gases and tailpipe emissions. The design must keep the original body design, and preserve safety and consumer standards. Teams are given technical specifications, such as a 0-60 mph acceleration time, energy usage, passenger capacity, and vehicle weight.

Over the 19 years that OSU has participated in the EcoCAR challenges, past teams have recorded actions that led to successes in their models. They also remember to warn future teams of previous mistakes, so that things can be done differently the next year.

Recalling his work in EcoCAR 2, M.J. Yatsko, graduate student and co-engineering manager of the EcoCAR 3, highlights the importance of refining the front-end design process to avoid problems while building the final prototype. "If you don't design the best one possible, it won't be the best one possible."

The team also refined their original eco-friendly theme, in order to ensure acceptance into the competition (only 16 schools out of 300 applicants were accepted to participate). Along with making a low-emission car, the team stressed their goals of making the transformed Camaro meet monetary, speed, and acceleration standards set by the average driver.

LEARNING FROM THE EcoCAR 2

Ohio State University's EcoCAR 2 team consisted of 15 graduate students and 30 undergraduates, and they represented a wide range of majors, including

20 MILLION INVERTERS
10 MILLION SERVOS
300,000 ROBOTS

Yaskawa. Proven. Worldwide.

Nobody enjoys a larger installed base of inverters, servos and robots around the world than Yaskawa. Our experienced engineers, proven technology and unsurpassed quality can all be combined to give proven solutions in which you can have total confidence.

In a recent internal study of 100,000 servo motors shipped, Yaskawa found that only 7 were returned for warranty repair. To put that in perspective, a typical out-of-box failure rate goal for manufacturers of brushless servo motors is 0.5% (or 500 failures per 100,000 motors shipped).

No matter how you add it up, nobody equals Yaskawa. Call us today.

YASKAWA

IT'S PERSONAL
YASKAWA

YASKAWA AMERICA, INC.
DRIVES & MOTION DIVISION
1-800-YASKAWA | YASKAWA.COM

For more info:
http://Ez.com/yai747

mechanical engineering, electrical engineering, business, and communications.

Fueled with E85 ethanol and powered with parallel-series plug-in hybrid electrical vehicle architecture, the Chevy Malibu was repurposed with a Global Vehicle Motor (GVM) series traction motor from Parker Hannifin. It helped reduce emissions by half and improved fuel economy.

The GVM line features lightweight motors with high-power outputs and low power consumption. The Chevy's new motor demonstrated 50 mpg performance while using only 315 watt-hours per mile of electricity.

For the EcoCAR 3, OSU plans to use another model in Parker Hannifin's GVM line. Since the OSU team requested Parker Hannifin's GVM before the prototype was finished, Parker engineers were able to incorporate features to meet the criteria generated by the team and in the challenge rules.

Collaboration between the two teams provided a learning opportunity for both parties: "That was something we didn't have with previous motor suppliers," says Yatsko. "Parker developed prototype motors for us, and although it was just going into production with their motors for automotive purposes, we needed them before they would be in that production phase. So they worked with us to design motors with the specifications we needed. Not only did we get motors specifically designed for us, but we went up to their test facility and did motor dynamometer testing so we could do validation and make sure the motors would work for us."

The Chevy Malibu and Camaro are different, one a high-performance sports car and the other a mid-sized sedan. However, motors in the GVM line are easily fitted to different cars, so the OSU team is going to use the same line again for EcoCAR 3. The new motor will use different diameters, lengths, and windings to fit into the new car and suit the new powertrain. "Any feedback we get from this competition will go into the next revision of our GVM," says Jay Schultz, Parker's Traction Motor Product Manager.

Combining the expertise of automotive engineers and the fresh, open minds of students produces innumerable opportunities for innovation and creative design. From the competition criteria and team goals, engineers learn what consumers and automotive industries are looking for in the future of clean-air automobiles. With the continuance of the EcoCAR competitions, the automotive industry hopes to spur innovation to produce smart, hybrid, and alternative-energy cars. ■

SOUND RESEARCH MAY TRANSFORM
the Future of Firefighting

EXPERIMENTS FROM THE past two centuries have shown the effects of sound on fire. In 2012, the U.S. Defense Advanced Research Projects Agency (DARPA) illustrated how noise from a large sound generator was used to extinguish a flame. Now, two students at George Mason University are applying the power of sound waves via a handheld sound generator to put out fires, with an eye toward eliminating the inconvenience of fire extinguishers and improving fire safety.

After a year of testing to see how fire responds to noise, electrical and mechanical engineering majors Viet Tran and Seth Robertson found the frequency range that would disrupt the oxygen flow necessary to fuel a fire. Between 30 and 60 Hz, a relatively low frequency range, the waves push the air molecules and oxygen molecules away from the fire at a rate that does not allow oxygen to fuel the fire any longer. In order to work, the frequency must remain constant; otherwise, the fire will fluctuate and is less likely to extinguish.

After determining the right frequency, the students needed to design a sound-wave extinguisher that was small and safe enough for use in households. The prototype consisted of an amplifier powered with a small power source, connected to a frequency generator. They made a collimator out of a hollow cardboard tube to direct the sound waves at the fire.

Since only ethanol-fueled fire was tested, the handheld noise fire extinguisher still needs to be tested on fires started from other sources. If successful, it could revolutionize household fire safety, potentially end messes caused by fire extinguishers and water damage, and decrease risks for firefighters. Because of the high speed and far reach of sound waves, a large sound-generating device could also be set up on forest-fire perimeters to improve forest-fire control. ■

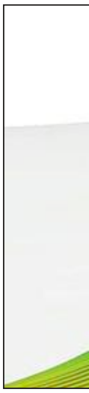
DIALYSIS TECHNOLOGY Lifts Off with Aeronautics Software

PATIENTS WITH KIDNEY failure depend on dialysis machines to replace most renal functions. A dialysis machine is responsible for filtering creatinine and urea from the blood, and moderating water content to control blood volume.

Now, aeronautic software will be used to significantly improve kidney dialysis technology, and no modest bioengineer can shrug off the achievement with "it's not rocket science" because, well, that's exactly what it has become.

A team consisting of bioengineers, aeronautic engineers, circulatory specialists, and cardiovascular surgeons in the U.K. are using aerospace fluid-dynamic software to simulate blood flow for different arteriovenous-fistula (AVF) configurations. An AVF is necessary to increase blood flow from the patient's arm to the dialysis machine.

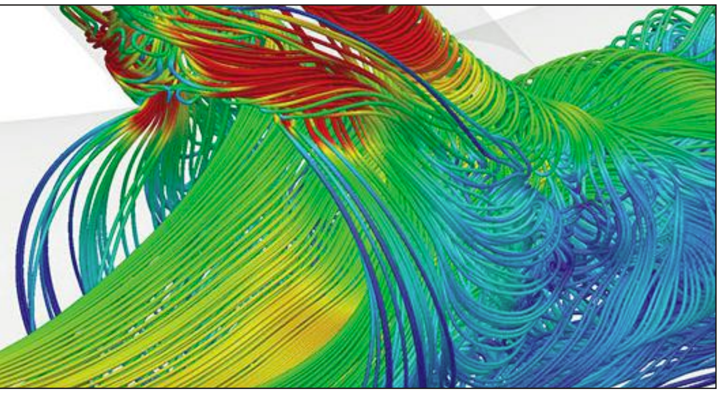
Before dialysis, a vein and an artery in a patient's arm are surgically connected to create an AVF, where blood flows directly from an artery into the vein, instead of passing through capillaries. The software, which caters specifically to a patient's blood vessels, analyzes the shear flow for different artery curvatures and vein-artery alignments to create the optimal AVF configuration for that person. Pictures of the patient's circulatory anatomy can be produced using ultrasound techniques.



WHAT IS AVF SURGERY?

AN ARTERIOVENOUS FISTULA (AVF) is surgically created by conjoining a vein and an artery. Normally, the high pressure in arterial blood is decreased gradually as the blood flows from the single artery to small, but numerous, arterioles that branch into smaller and more numerous capillaries. (Although capillaries and arterioles have smaller cross-sectional areas, the high number of them yields a large total cross-sectional area, therefore reducing blood pressure.) From the capillaries, the blood flows into larger venules and then into a single vein, where the pressure remains relatively low.

By creating a fistula, the gradual decrease in blood pressure is replaced with direct high-pressure blood flow from the artery into the vein. Before the patient starts dialysis, he/she must wait several months for the vein to strengthen itself against the direct high pressure. This creates a strong flow from the artery to the machine, and allows the same flow rate back into the vein.



Credit: Peter Vincent/Imperial College London

BECOMING STRESS-FREE

AVF surgery can be problematic because the surgeon alters the trajectory of normal blood flow though the vessels. If the transition between the vein and artery is not smooth, eddies may develop, and the laminar flow becomes turbulent. Such an imperfection could cause shear stress on the blood cells during blood flow. Shear stress is a key instigator for blood clotting, so when AVF surgery goes wrong, it can sometimes result in a clot.

Shear stress on the blood cells during flow can also be triggered by an extreme curvature of the artery when connecting it to the vein. The blood cells hit the edge of the artery wall during flow, producing shear stress and possibly resulting in a clot. Furthermore, AVF configuration could affect oxygen transport.

For these reasons, surgeons require a way to predict the blood flow profile in different AVF configurations. Blood flow is also different from patient to patient. “Our ultimate aim is to use computational simulation tools to design tailored, patient-specific arteriovenous-fistulae configurations that won’t block and fail,” says Peter Vincent, a senior lecturer and fellow of the Engineering and Physical Sciences Research Council (EPSRC) in the Department of Aeronautics at Imperial College London.

After analyzing many different AVF configurations with the aeronautic software, the team found the optimal setup for stabilizing blood flow and reducing shear. “We discovered that if an arteriovenous fistula is formed via connection of a vein onto the outside of an arterial bend, it stabilizes the flow,” says Vincent. The process has yet to be tested clinically, but so far, it seems that rocket science and bioengineering have more in common than we thought.

To learn more, read the published report in the *AIP Physics of Fluids journal*. ■

REFRIGERATOR GOES GREEN
(...and we're not talking produce)

TO SAVE ENERGY, room, and reduce noise and oil use, Whirlpool Corp. and the U.S. Department of Energy at Oak Ridge National Laboratory have joined forces to design a green refrigerator. The fridge will use a Wisemotion linear compressor developed by Embraco, along with other energy-saving components, to produce a more efficient and effective cooling system.

To drive the piston for refrigerant compression, early compressors from the 1970s and improved models from the 1990s translate rotational motion to linear motion. In those 1970s models, a mere one-speed motor powers the rotational axis, turning on and off to regulate the refrigerator's temperature. This model could use up to 5 kWh per day.

Redesigned compressors from the 1990s employ variable-capacity motors to rotate the axis at variable speeds for refrigerant pumping regulation, instead of powering on and off. This method reduces noise, better regulates cooling, and decreases the energy cost of switching on and off to approximately 1 kWh per day. Both eras' compressors require oil to lubricate the axial moving parts.

Now, with Embraco's Wisemotion compressors, the new refrigerator's energy consumption will fall below 1 kWh per day. Created in the early 2000s, Wisemotion compressors don't require translation from rotational to linear motion to move the piston. Rather, motor-powered linear spring displacement directly drives the piston.

Removal of the rotating parts lowers noise and eliminates the need for oil lubrication—moving parts instead use the refrigerant gas for lubrication. To save power as well as keep food fresher for longer, Wisemotion maintains a minimum piston stroke displacement, keeping the refrigerator above a minimum temperature setting and lengthening stroke for a higher refrigerant pump rate.

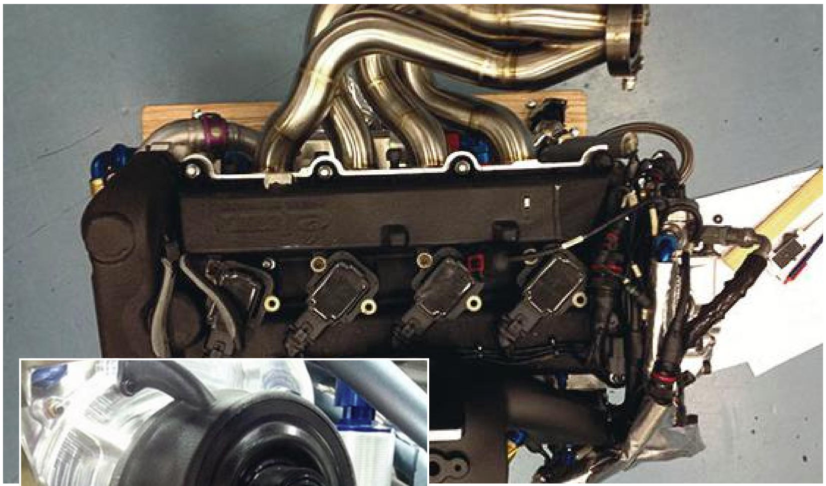
The new fridge is expected to cut electricity bills by $26 for the average consumer. If the green fridge were to replace every refrigerator in the U.S., estimates show that it would save 0.56 quads per year—equivalent to 100 million barrels of oil, according to Ed Vineyard, director of ORNL's Building Technologies Research & Integration Center.

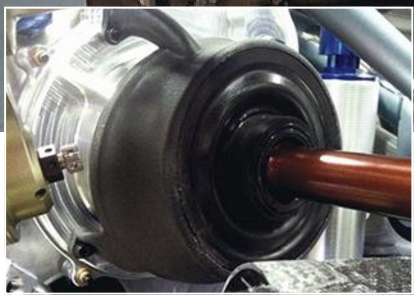
The team expects to come up with new designs for more efficient heat transfer, insulation, and new refrigerants. It's hoped that within three years, the new design will change refrigerators for the better overall, and that these new technologies will likely affect other HVAC applications. ■


ENGINEERS START HERE
Access 500,000 in-stock electronics products, custom services, tools and expertise—all in one place. Plus, count on customer service that goes above & beyond to deliver your needs. Complete engineering solutions start at Newark element14.
1 800 463 9275 | newark.com
Newark
element14

3D-PRINTING MATERIAL Lightens Racecar Load

TO IMPROVE THE DeltaWing racecar's power efficiency during acceleration and turns, Ben Bowlby and his team of engineers felt the best solution was to decrease the car's weight. Thus, they decided to replace internal components with lightweight, high-performance 3D-printed parts. Not only did it lower the weight, but it improved the vehicle's structure and internal efficiency, as well as simplified the design process. The lightweight racecar was successfully test-driven at the 24-hour Lemans race and in the U.S. Petit Le Mans.





The final gearbox with integral bell housing weighed only 33 kg.

A 3-D printed intake manifold for a DeltaWing race car was made out of Windform XT 2.0 in order to simplify manufacturing and decrease the weight of the automobile, all while withstanding high temperatures and pressures of the gearbox oil.

Windform 3D printing materials are made from a range of polyamide powders suited for selective laser sintering (SLS) in additive manufacturing. The DeltaWing car used Windform XT 2.0, a polyamide-based composit reinforced with carbon fiber that complies with ASTM E-595-07 standards. Heat resistant, durable, and lightweight, it's suitable for aerospace as well as motorsport applications.

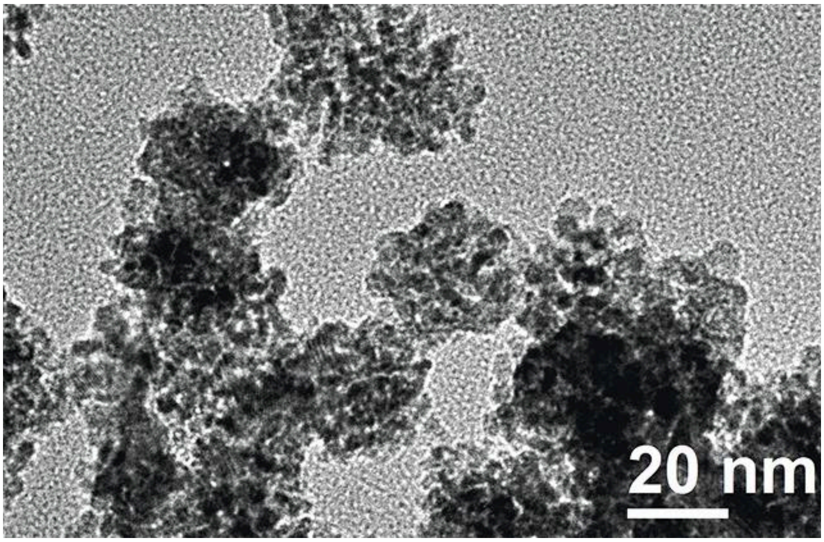
To significantly decrease mass, Zack Eakin, a DeltaWing engineer, proposed that the team replace the racecar's gearbox siding with Windform XT 2.0. He designed a non-stressed member engine and gearbox that would reduce vibrations on the lightweight components. In the end, the gearbox with integral bell housing weighed only 33 kg.

The new availability of this robust 3D-printing material also allowed the team to make other key changes to benefit the car. Windform XT 2.0's resistance to high temperatures and pressures allowed the DeltaWing team to redesign oil flow and gearbox structure to reduce parasitic losses. The team easily fabricated an otherwise complicated 3D-printed piece with integral oil drillings, a task that would typically require a 5-axis manufacturing process.

In addition to the new gearbox design's transmission seal covers with pressurized oil-feed passages, the team used Windform XT 2.0 to additively manufacture electronics enclosures, electrical breakout boxes, and a tow hook plinth. In the prototyping and tooling phase, Windform XT 2.0 was applied in brake inlets and ducting, air inlet ducting, and filter enclosures. ■

EXCESS RARE EARTH METALS
Could Facilitate Nylon Production

USE OF (NOT-SO)-RARE earth metals in large-scale manufacturing applications is expected to economize critical rare earth excavations. Just to be clear, not all rare earth metals are necessarily rare or difficult to obtain and process. Some can be as common as copper, while others have low accessibility or are tough to extract from their natural surroundings. Both types are crucial in everyday technologies, putting the "rarer" rare earths at high demand and low supply.



An electron micrograph shows the catalyst on high surface area ceria.

A main goal of the Critical Materials Institute (CMI), a U.S. Department of Energy Innovation Hub led by Ames Laboratory, is to level out the supply and demand of critical rare earth metals. To accomplish that task, CMI scientists are finding alternatives to these rare earths in technology, researching new recycling methods, and improving the extraction of key rare earths from other substances.

And now, CMI is adding a new approach, with a focus on the common rare earths.

Since common rare earth metals are often picked up when mining for their critical counterparts, scientists at CMI hope to find large-scale uses for them. Such critical rare earth excavations would then have added value in terms of time and money, as well as optimize mining resources.

CMI created a method using cerium, the most common rare earth, to improve the production process of nylon. Everyday appliances, from rope to stockings, are made out of nylon, which makes for a rather wide and diverse industry.

To create nylon, a hydrogenation step is necessary to convert phenol into cyclohexanone. Traditional nylon production requires high temperatures and pressures, as well hydrogen, which can be hard to handle and store, let alone posing safety risks

CMI scientists, along with the department of Chemistry at Iowa State University and Oak Ridge National Laboratory, successfully created a method to catalyze the conversion. It's performed at ambient pressure and room temperature, and doesn't require high levels of hydrogen. A cerium-based material called high-surface-area (HSA) ceria is used as a scaffold to palladium, which acts as the catalyst. The HSA ceria platform contains nanometer particles that distribute the catalyst in reduction reactions. The full chemical reaction is detailed in the *ACS Catalysis Journal*. ■

JEFF WARREN | CEO and Chief Engineer
The Warren Group, Irmo, S.C., www.warrenforensics.com

Why Interlock Guards Trump Lockout/Tagout

MANY OF THE ANNUAL 3.3 million workplace injuries result from broken OSHA rules. Andd of the top 10 OSHA rules most frequently broken, two directly concern machine design: lockout/tagout procedures (LO/TO) and machine guarding. Engineers designing machinery must often choose whether to protect workers by designing-in interlocked guards or adding them later, or by relying on operators and maintenance technicians adhering to LO/TO. The safest route is to use interlocked guards. Let's see why.

A lockout tag carries a warning not to remove the tag and start the machine, along with information on who locked out the machine and why.

INTERLOCKED GUARDS & LO/TO

Engineers designing machinery should always eliminate hazards if they can, according to the System Safety Design in Order of Precedence for Mitigating Hazards, often called the Safety Hierarchy. If they can't, then they should design safeguards into the machine that prevent workers from coming into contact with hazards.

One effective safeguard, interlocked guards, stops machines from operating when a barrier is opened or removed. They are more effective in preventing injuries than LO/TO procedures that workers might not follow and companies might not enforce. If safeguards are not feasible, warnings must be issued about the machine's hazards and risks. Finally, proper training and procedures such as the company's LO/TO policy should be established, promulgated, and followed.

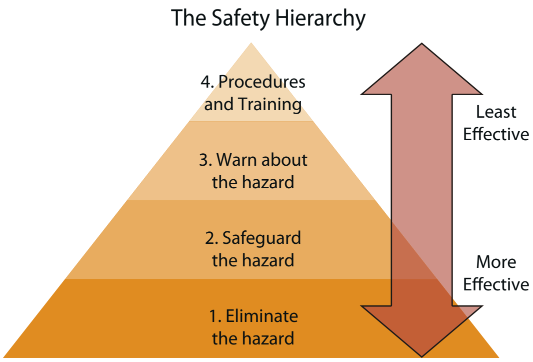
Properly implemented, LO/TO provides a high degree of protection. Its weakness lies in the foreseeable, predictable failures of workers to always follow the policy.

It is common for employers to fault workers for accidental injuries or deaths because "they were trained and should have known better." Employers often terminate workers for failing to properly LO/TO a machine before it is serviced, a violation of OSHA standards that can result in an OSHA citation. Most workers know that violating LO/TO policies is an "at-risk" behavior that can cause serious injury or death, and even if there are no accidents, violations could still get them fired. Therefore, it seems illogical that any employee would violate LO/TO standards. Yet it happens.

DESIGNER'S DILEMMA

It's easy for engineers to ensure a paragraph is put in the operator's manual saying that employees should LO/TO a machine before removing a guard to service or maintain it. This makes it easy for engineers to fault employers who receive OSHA LO/TO citations and injured employees who commit violations.

However, the ultimate goal for machine designers should be to come up with machines that have proper safeguards, if reasonably possible, that anticipate and tolerate user errors, mistakes, and violations. It is irresponsible for engineers and machine manufacturers to shift responsibility to employer or employees by requiring LO/TO when a hazard should really be eliminated or safeguarded through design. Therefore, engineers should always determine if an interlocked guard should be installed on machines requiring routine, repeti-



Engineers designing machines that will be used or serviced by human operators have a duty to perform a risk analysis and use the most effective means possible and feasible to prevent injuries.

tive service or maintenance during normal production. Only as a last resort should engineers or machine manufacturers rely solely on LO/TO.

Failure to provide interlocked guards on machines that should have them is a design defect that may lead to product liability claims against the machine manufacturer. But other than avoiding large verdicts, why provide interlocked guards? The answer is that interlocked guards provide an effective, alternative form of protection that tolerates worker errors and prevents workers from being injured. And worker errors, mistakes, and rule violations are inevitable.

WHY LO/TO FAILS

Workers do not wake in the morning and decide to go to work, make mistakes, and get hurt. In behavioral science, there is significant research on human error and why people make mistakes. Designers should understand this science. For example, in the recent book, Safe by Accident: How to Take the Luck Out of Safety (2010), the authors describe the ABC model of behavior. It says that behavior (B) is influenced by the antecedent (A) or what comes before, and the consequences (C), or what follows.

Every behavior has consequences that have one of two effects: they either increase or decrease the likelihood of repeating that behavior. The pattern of consequences determines the performer's behavior.

Authors Agnew and Daniels note that "if the pattern of consequences favors at-risk behavior, then at-risk behavior will occur. If the pattern favors safe behavior, then safe behavior will occur." If a worker believes that cleaning a machine without shutting it down properly contributed to (or favored) increased productivity, then they would continue that behavior--especially if there were no perceived negative consequences to themselves.

The power or strength of each consequence is also determined by the timing and probability of a consequence. Daniels and Agnew state, "Consequences that are immediate are much more powerful than those that are in the future." Furthermore, consequences that are certain are much more powerful than uncertain ones. The strength or power of any consequence can be analyzed by determining whether it is positive or negative, immediate or future, certain or uncertain (as shown in the PIC/NIC Analysis diagram).

As the Daniels and Agnew document makes clear, "It is all too clear that employees can and will engage in unsafe behavior to get stuff out the door."

Machine design can tolerate and resist at-risk behavior by including safety mechanisms such as interlocked guards. Therefore, designing machines that can be used safely and tolerate foreseeable human behavior is paramount.

In general, two main types of errors cause workplace accidents: slips and lapses. Slips are actions that do not go as planned, such as a slip of the hand, slip of the tongue, or slip of the pen. They are often preceded by a distraction or preoccupation.

Distractions are common in workplace environments. Lapses, on the other hand, are largely failures of memory. Lapses do not necessarily show up in actual behavior and may only be obvious to those who experience them. Errors of any kind are a guaranteed part of

human behavior and an unfortunate certainty in the workplace.

Mistakes differ from errors. Errors are unplanned. Mistakes can happen when actions are performed according to plan, but the plan is inadequate to yield the desired outcome. Mistakes can also be failures in judgment. In terms of human behavior, mistakes are more subtle, more complex, and less understood than slips or lapses. As a result, they constitute a far greater danger.

Violations are somewhat different. They are not a direct component of individual human behavior, but are made in the context of some society norm in which behavior is governed by operating procedures, rules, and codes of practice. Violations are deviations from those practices deemed necessary by designers, managers, or regulatory agencies to maintain safe operations of a potentially hazardous system. They can be inadvertent or intentional, and unfortunately can become routine.

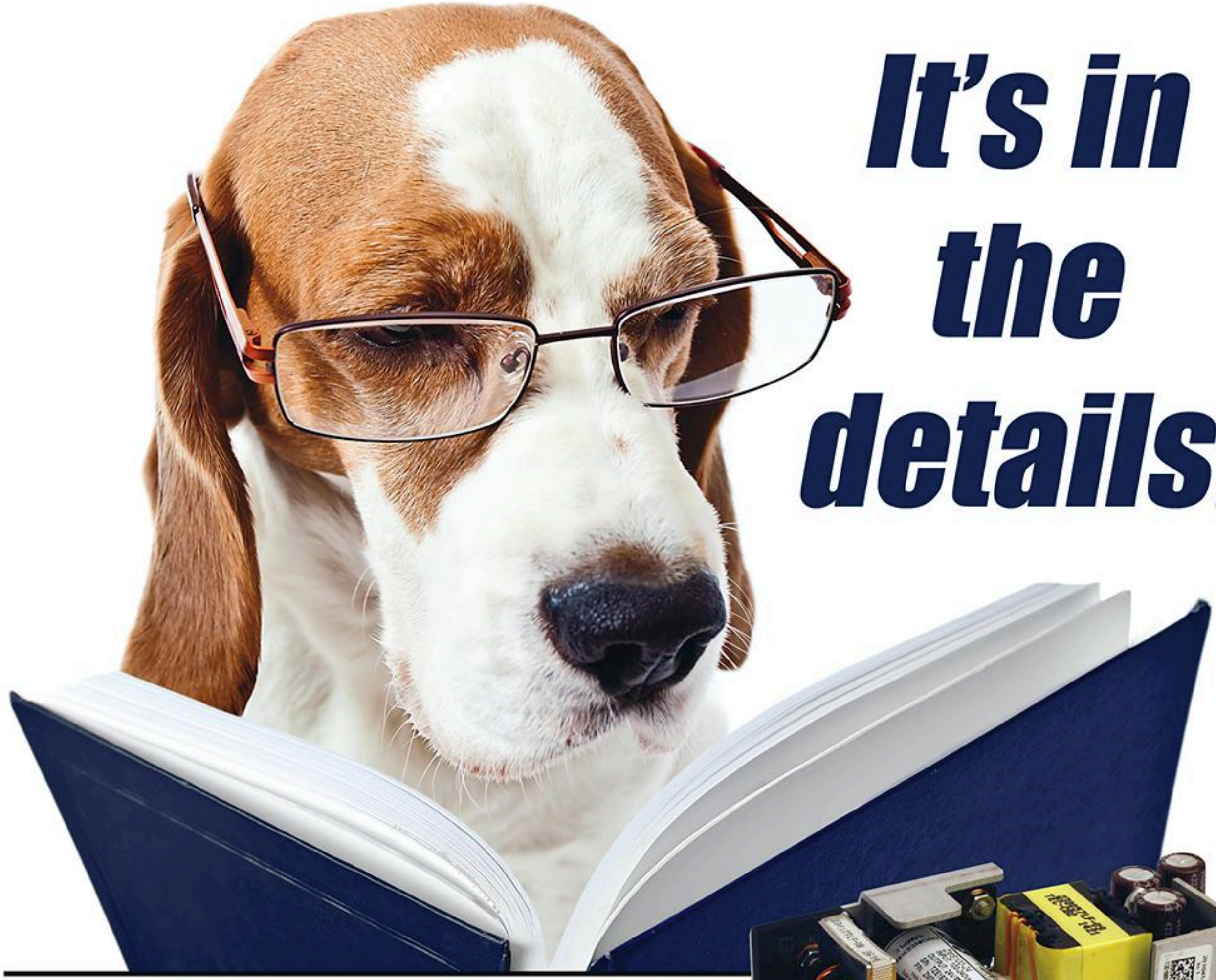
People often make routine violations because of a natural tendency to take the path of least resistance. Violations frequently occur when employees work in relatively indifferent environments and rarely get punished for noncompliance or, conversely, are rarely rewarded for compliance. In his book, Human Error (1990), James Reason states, “Everyday observation shows that if the quickest and most convenient path between two task-related points involves transgressing an apparently trivial and rarely sanctioned safety procedure, it will be violated routinely by operators.”

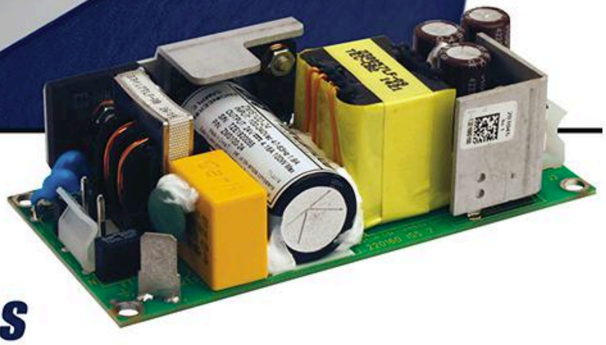
Sadly, it only takes one mistake, error, or violation to be fatal. Reason adds, “Such a principle suggests that routine violations could be minimized by designing systems with human beings in mind at the outset.”

While designers, manufacturers, employers, and policy creators encourage workers to be careful, minimize errors, and follow proper procedures for safety, expecting workers to be “perfect” is unrealistic. It won’t happen. Therefore, machine designers should expect the worst and design machines to accommodate errors, mistakes, and violations where reasonable, or technologically and economically feasible. Machines should tolerate errors, mistakes, and violations, if the risk is acceptable and it is reasonable to do so.

The science of human behavior demonstrates that errors, mistakes, and violations are inevitable. Safety through design tolerates these errors. Safety through design also tolerates human at-risk behavior, and interlocked guards are a shining example. A machine with an uncontrolled hazard that can result in death or serious injury is, in most circumstances, unreasonably dangerous and defective if the risk is unacceptable and it is technologically and economically feasible to install a safeguard such as an interlocked guard. Furthermore, failing to provide interlocked guards may result in a products liability case against the machine manufacturer. md

It's in the details!





ZMS SERIES

Long Lasting Power Supplies

Wanting a 2 x 4″ that will go the distance? Check out TDK-Lambda's new ZMS100; a power supply that has been meticulously designed and tested.

The ZMS100 will reliably deliver 80W convection cooled or 100W with forced air and has both IEC 60950-1 (ITE) and IEC 60601-1 (Medical) safety certifications.

Don't remain doggedly fixed looking for a solution, contact TDK-Lambda for an evaluation unit or check our website for distribution inventory.

http://us.tdk-lambda.com/lp/products/zms-series.htm

- Industry standard 2 x 4″ footprint
- 80W convection, 100W forced air
- Up to 89% efficient
- Output voltages 12, 15, 24, 36, 48VDC
- ITE & Medical certifications (2xMOPP)
- Class I & II operation
- Long capacitor lifetimes

For more information on how **TDK-Lambda** can help you power your unique applications, visit our web site at **www.us.tdk-lambda.com/lp/** or call **1-800-LAMBDA-4**

TDK

Interview

BRAM DE ZWART | Founder
3D Hubs

A Tech Futurist Looks at the Fate of 3D Printing

What is your background?

I have a background in Strategic Product design, having studied at Delft University of Technology. I wrote a thesis on the promise of 3D printing and new business opportunities. I then joined 3D Systems as a product manager working on Freshfiber and Freedom of Creation consumer brands.

What led to you starting up 3D Hubs?

While working at 3D systems, Brian Garret (co-founder of 3D Hubs) and I discovered that most 3D printer owners only use their printers on occasion and that 95% of the time the printer just sits around. We saw an opportunity to bring manufacturing much closer to the end-user, which is the real promise of 3D printing. We really wanted more people to get easy access to this world-changing technology.

We started talking to some printer owners to find out if they would be open to print for others, and got an overwhelming response; our idea of 3D Hubs was born. Six months later, in April 2013, we quit our jobs and launched 3D Hubs. Now, two years later, we have a network of over 14,000 3D printing locations in 147 countries. 3D Hubs is the world's largest and fastest-growing network of 3D printers, giving over 1 billion people access to a 3D printer within a 10-mile radius of their home.

What are some of the key components that can be expected to shift if people move to a 3D print consumer market?

We're making big steps toward making 3D printing more accessible to consumers, but I do think that when we get there the 3D print consumer market will have a huge impact on how products are made (this is already happening) and consumed. That will impact a lot of big companies now using traditional manufacturing for their products.

The 3D printing technologies have a lot to offer to produce on-demand products and allow easy customization.

Could this impact manufacturing and prototyping companies?

Certainly, this opens new opportunities for manufacturing and prototyping companies. Additive manufacturing isn't new, what's new is that individuals are getting access to those techniques with desktop 3D printers. Community-run micro operations could substitute today's factories. Products could be made on demand and closer to their point of purchase, with both individuals and companies driving their design and innovation. Everyone can become a designer and manufacturer.

How big of an effect could 3D printing have on brick-and-mortar stores?

Digital manufacturing technologies (such as 3D printing) are rapidly changing the way we design, manufacture, and distribute end-consumer products. I believe consumer will expect faster production times, higher availability, and customization of products. That means stores will need to anticipate changing consumer needs.

Are there any concerns or features of a 3D printed market, such as copyright infringement?

The rise and adoption of new technologies raises new concerns. Copyright infringement is one of them. I believe we have to address these issues so that the concepts of intellectual property and copyright infringement stay clear to everyone. Regulations need to adapt new dynamics of the digital age and keep pace with the new developments of the technologies.

Could an on-demand society lead to more waste?

I'm a true believer in a service-based economy in which we don't have to own "things," but we just need access to solutions. People want access, not ownership. It would solve a lot of inefficiencies and eliminate waste in this world.

Let me sketch why a collaborative network of 3D printers could be the future: community-run micro operations could replace today's factories. Products could be made on demand and closer to their point of purchase, with both individuals and companies driving their design and innovation. Once

used en masse, we would cut down transport pollution and long shipping times of the current centralized production processes. Suddenly, making and distributing stuff would not only be cheaper and better for the environment, but great for local economies as well.

By going from idea to product so quickly, do you feel there might be a quality concern on the products made this way?

In a product-design workflow, iteration is key to a successful creation. By going from idea to product faster than with previous methods, 3D printing allows faster iterations. I truly believe that an increased number of iterations leads to better products in the end. It shortens the innovation cycle and allows us to beta-test faster. We're moving away from linear production, but continuous improvement of products, which will hugely increase quality. Our partnership with Fairphone, printing smartphone cases on-demand and locally, demonstrates that there's a demand for ready-to-use 3D printed products. Most of those cases are printed out of PLA, a biodegradable plastic, on desktop printers. Results and customer satisfaction were over our expectations, so it is encouraging for the future.

How can an at-home printer compete with a larger 3D printing service?

We are developing more tools that allow our Hubs to run their own operations more smoothly and be more useful to our customers. This way, we allow at-home printers to leverage our brand and tools to complement centralized 3D printing services. We're trying to match the right printer to the right person depending on the printing task. In other words, at-home printers are complementing professional machines.

Where do you see the future of 3D printing going, and what are your hopes for the future of the industry?

I want my mother to 3D print! Right now it's mainly used by early adopters and designers, but I want everyone to start using 3D printing and contribute to efficient manufacturing. 3D printing promotes local, community-based creation. And for on-demand production, it's very fast. It takes just a few hours to make something through our platform. Print speeds are getting faster with every new generation of printers. There's also a lot going on in the R&D of new materials. Ingenious new materials will pave the future of the industry toward more efficiency and better usability. md

The Angle Sensor Called "Ultra-Reliable" . . .

...Also Delivers Ultra-Value

Automotive racing can present a very demanding environment for race car parts. That's why when race team engineers choose the SP2800 and call it "ultra-reliable", they speak from years of direct experience. Proven in **applications from industrial valve controls to robotics, mobile steering** and more, the SP2800 Series is also easy to mount and has great price/performance.

Key specifications are:

- Electrical angles 0° to: 100, 130, 308, 340 and 345°
- Repeatability to 0.01% (0.03°)
- Life: 50 million movements
- Ingress protection rating to IP 65, IP 67 optional
- Independent linearity to ±0.3%

For complete SP2800 information visit www.novotechnik.com/sp2800

novotechnik
Siedle Group

Novotechnik U.S., Inc.
Telephone: 508-485-2244
Email: info@novotechnik.com

ASHOK AMIN | Mining & Material Handling Segment Manager, North America
Bosch Rexroth Corporation, *www.boschrexroth-us.com*

Industrial Workhorses: LARGE HYDRAULIC DIRECT DRIVES

Key features, functions, and application considerations for large hydraulic material handling systems.

Across the globe, there has been significant investment into, and expansion of, many industrial segments requiring heavy-duty material-handling systems. These applications often operate continuously, lift and transport loads ranging from hundreds of pounds to several tons of material, and are frequently located in environments—mines, power plants, shipyards, ports, and terminals—with rugged operating conditions.

Large hydraulics have proven to be effective when a heavy mass needs to be moved under variable speeds using a system that can handle shock loads (sudden increases in the weight and mass of loads being moved) with the ability to deliver energy-efficient and reliable performance—typically operating 24 hours a day, seven days a week.

OPERATIONAL AND APPLICATIONS CRITERIA

The most common uses of hydraulic direct-drive systems are for industrial applications moving heavy masses on a continuous basis with low speed and high torque, and especially high starting torque (~2000 kNm) for operations with frequent stops and starts. Steady, continuous high torque is essential—loads need to be moved as part of a constantly operating process, with minimal downtime and a limited number of failure points within the drive technology.

Key examples of these types of applications are ore and mining conveyors; feeders, crushers, drums, massive bucket wheel reclaimers, and excavators in mining and material-handling applications; rail car and ship unloaders at ports and terminals; and bulk material movement systems at cement plants and coal-fired power plants.

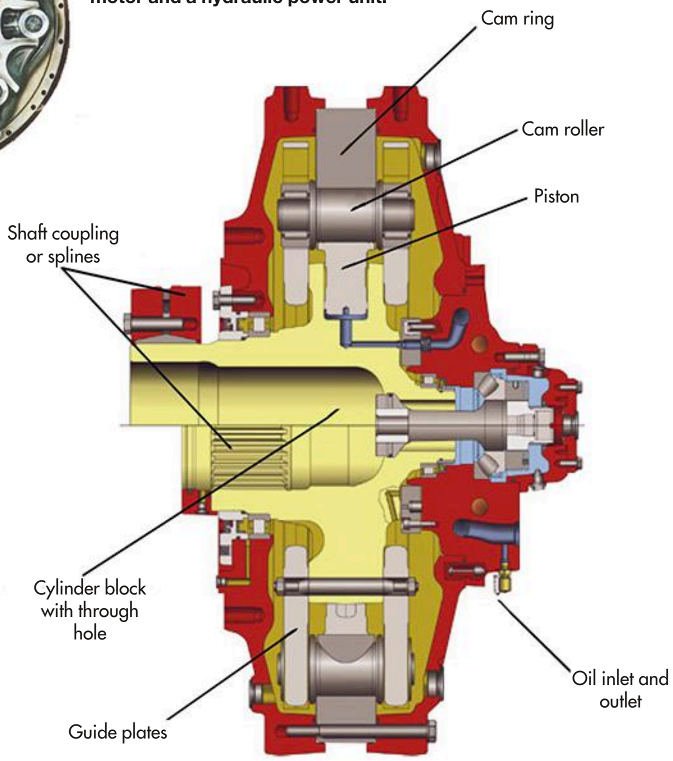
Hydraulic direct drives also perform well in applications where "shock loading" occurs: large, heavy loads are dropped onto moving conveyors, feeders, crushers, or turning drums that suddenly vary the load size by several tons during the course of normal operations. The drive has to be able to respond to the shock load without undue wear-and-tear on drive components and continue driving the material movement system smoothly.

COMPARISON OF DRIVE OPTIONS

Different drive technologies can be used to operate these systems, each featuring different output characteristics of both speed and torque. They also have different components

The newest hydraulic direct drives now being offered combine smaller sizes and lighter weight with much higher power density.

Large hydraulic direct-drive systems for low-speed, high-torque operation typically consist of a hydraulic radial piston motor and a hydraulic power unit.



The image above displays a cutaway view of a large hydraulic direct drive that has the radial piston cam curve unit.

and operating characteristics that are helpful to consider.

Electromechanical direct-current (dc) drives: These systems, which do have wide use in many older installations, include dc motors that are typically rated for high rotation speeds—900 to 1800 rotations per minute (RPMs). To provide low-speed, high-torque operation, a mechanical gear reduction box is installed between the dc motor speed coupling and the driven shaft of the material handling system. There are several disadvantages associated with this configuration. The gearbox is essentially over-dimensioned and less reliable; the gear ratio is fixed, which does not allow flexibility in operating at optimum speeds; and the gearbox elements themselves also require maintenance and repair. In many of the operating environments described above, heat and dirt are unavoidable and can impact the gearbox operation significantly.

Electromechanical variable frequency drives (VFDs): This option is similar to the dc drive option and, in recent years, has replaced that technology. It combines a frequency converter, an electric ac induction motor, and a high-speed coupling, and provides a variable-speed option. Similar to the dc system, the electric drive operates at high RPMs; for low-speed high-torque applications, a gear reduction unit is also required. The attendant inefficiencies associated with gearbox coupling of the drive system to the driven axis are similar.

Hydraulic axial piston motors: These hydraulic motors have pistons driven by hydraulic pressure reciprocating in/out of chambers to rotate the motor's output shaft, which can be coupled directly to the driven axis. Piston motors generally run at higher speed rotations; for the high-torque lower-speed applications under discussion here, it may be necessary to utilize a gear reducer to achieve lower-speed operation.

Hydraulic vane motors: These hydraulic systems are directly coupled to the driven axis of the feeder, conveyor, or other material-handling systems. They are a lower-speed, high-starting torque radial motor that uses pressurized hydraulics to push against a series of overlapping vanes within the motor to turn the shaft. They offer higher RPMs than direct-drive radial piston motors and provide high torque at both start and stall, along with flat torque throughout the entire speed range.

While both the electromechanical and hydraulic options described here provide reasonably acceptable performance for driving high-load material-handling systems, large hydraulic radial direct-drive motors offer unique advantages. These are worth considering for applications calling for high-torque, low-speed operation.

LARGE HYDRAULIC DIRECT-DRIVE TECHNOLOGY REVIEW

Large hydraulic direct-drive systems for low-speed, high-torque operation typically consist of a hydraulic radial piston motor and a hydraulic power unit. The hydraulic radial piston motor is a hydraulically balanced radial piston cam curve unit. It is connected directly to the driven shaft. Pressurized hydraulic fluid is fed into the cam chambers. The fluid moves the pistons, which are mounted around the drive shaft in a radial direction, rotating the drive shaft. The radial piston motor has a high efficiency rate (close to 97%) approaching the energy-transfer efficiency of a roller bearing.

The radial piston motor is a fixed displacement and bi-directional unit, able to change rotation direction and speed with simple command control. Its typical operating range offers torque up to 2,000 kNm and a rotational speed up to 550 RPMs. Most importantly, this design delivers constant torque throughout the speed range, and unlimited starts and stops with the high torque demanded at each restart.

As part of the motor frame, it can be flange-mounted or torque-arm-mounted to take out reaction force while eliminating undesirable forces on the motor bearings. This is accomplished by positioning the flange or torque arm in relation to the load being driven. The pivot attachment allows the motor to follow shaft deflection with three degrees of freedom without overloading motor bearings.

The hydraulic power unit supplying the radial piston motor consists of a fixed-speed electric motor driving a variable displacement axial piston pump, a pump controller, a fluid monitoring system, and a hydraulic fluid reservoir. The power unit connects to the radial piston motor via cabling and hydraulic hoses; this has the advantage of enabling system designers to position the pump, electric motor, and controllers in an enclosure away from the operational axis for greater design flexibility and to protect these components (particularly electronics) from harsh operating conditions.

KEY DIRECT DRIVE ADVANTAGES

Hydraulic direct-drive technology of radial pistons has been adopted in many environments, but technology advances—smaller size and weight, along with offering the highest power density and high torque at low speeds—makes it viable for an expanding range of applications.

In particular, hydraulic direct drives offer a particularly effective alternative (or even retrofit replacement) for electromechanical drive options, for the following reasons:

Power density: Almost all the energy of the hydraulic system transfers to the axis of rotation to perform the work.

The hydraulic direct drive is powered by a fixed-speed ac induction motor and a variable-displacement pump.

This makes it well-suited for conveying and transport systems that don't require high RPMs to turn the axis of motion, but do require high torque.

Energy efficiency: There is no need for bedplates, couplings, or gear reducers between the motor and the driven shaft. As there are no high-speed elements that need speed reduction, the hydraulic motor can develop its exceptionally high torque from zero to full speed. This allows for excellent controllability of the feeder speed for all material conditions.

High torque on demand: The system supplies a high torque in the range of 2,000 kNm at startup and allows, through changes in the pump output, changes in the speed and torque being supplied as needed for the given load cycle instantly.

Reliable start and stop operation: The system does not undergo shocks when restarting and has a smooth power curve from a soft start, thus minimizing impact on the equipment being driven (e.g., belts on conveyors).

Designed for operation: Compared to electromechanical systems with gear

Large hydraulic radial direct-drive motors offer unique advantages worth considering for applications calling for high-torque, low-speed operation.

reduction, hydraulic direct drives have fewer parts to undergo wear and tear; this helps maximize equipment uptime, eases maintenance requirements, and makes these systems more reliable and able to deliver higher levels of uptime, particularly in rugged operating environments.

While widely used, it has been shown that complex gear reduction systems used in other drive platforms demand higher levels of maintenance, parts replacement, and, in many applications that undergo shock loading, higher rates of failure and replacement than many operators would prefer. With shock loading, the repeated and sudden variations in load (unavoidable in applications as diverse as mining, power plants, and scrap metal movement) cause the variation in load to be transferred back through, and physically impact, gearing and other components.

In a hydraulic direct-drive system, the hydraulic fluid acts as a spring, much more efficiently absorbing the load variation without transferring the mechanical energy to the motor or pump components. In addition, gear reduction actually wastes power in low-speed, high-torque operating conditions, rather than maximizing the power density of the drive system.

KEY USAGE CONSIDERATIONS

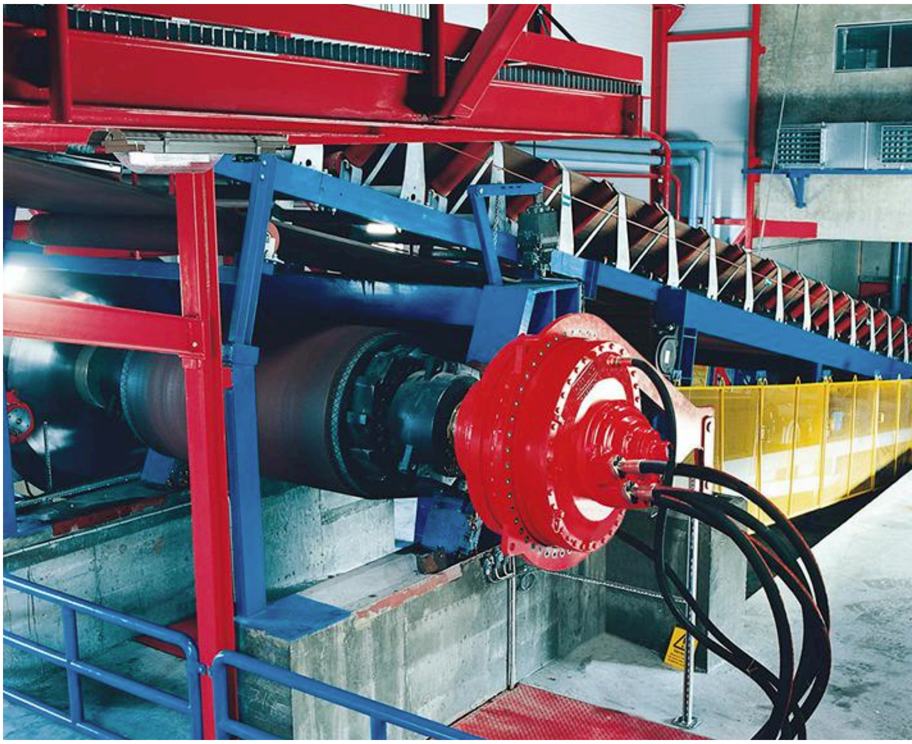
As system designers assess the drive technology to be used for high-volume, heavy-duty transport systems, there are several additional considerations to take into account when evaluating the potential of hydraulic direct drives:

Four-quadrant operation: Four-quadrant operation means the motor can provide both driving and braking action in both directions. Radial piston motors can change rotation direction through a simple controller signal, then switch back to their origi-

nal direction without impacting overall system performance.

Compact power: The newest hydraulic direct drives now being offered combine smaller sizes and lighter weight with much higher power density. This enables more options for implementation in a wider range of applications. They can fit into tighter machine locations and be mounted directly on the main drive axis of a bucket wheel excavator without adding significant excess machine mass or weight.

Tandem systems: For applications requiring higher torque than a single radial piston motor can offer, two or more hydraulic motors can be mounted in a tandem configuration, with a single hydraulic power unit configured to support the mul-



Large hydraulic radial direct-drive motors offer unique advantages worth considering for applications calling for high-torque, low-speed operation.

tiple motors. This can be two motors driving a single axis or, alternately, four motors driving two axis (at both ends of a conveyor, for example); this is an easier way to ensure that both motors carry a common load, since the hydraulics are all part of the same closed-loop circuit sharing the load naturally. It also multiplies the power advantage of hydraulic direct drives. One example of a solution combines four direct-drive motors powering multiple pulleys to create a 5,000-hp conveyor drive.

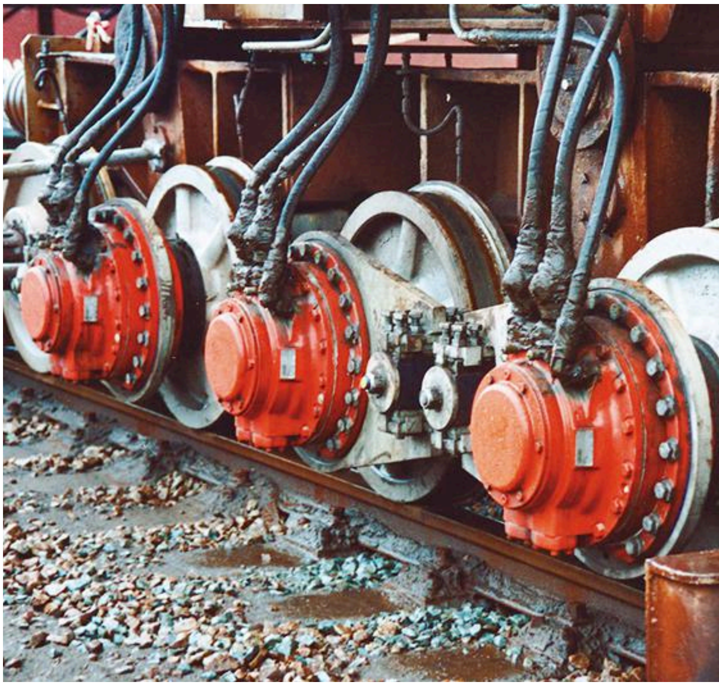
Retrofit solutions: For existing facilities that seek to capture some of the benefits associated with hydraulic direct-drive systems, minimal reconfiguration is required to replace electromechanical drives with hydraulic direct drives. Particularly for large-scale resource and bulk material-handling operations that can experience significant losses due to a gearbox failure, hydraulic direct drives can be married with an existing conveyor axis or other equipment in comparatively short time.

Total cost of ownership: Although electromechanical solutions may have a lower initial cost of ownership, there are some lifecycle factors that system designers and end-user operators should consider when assessing the potential for hydraulic direct drives:

- High reliability of hydraulic direct drives due to low moment of inertia and high shock load resistance. This practically eliminates the need for coupling alignment, and there is no risk of gearbox failure with hydraulic direct drives.
- Space savings and weight savings with many indirect cost savings.
- Cost of electricity. Using dc or VFD high-speed electric motors and over-dimensioned gear boxes can require more energy to operate over a wide range of speed and various load capacities compared to hydraulic direct drives. These do not require over-dimensioning, and the modular sizing of electric motor and pump combinations allows more flexibility to optimize costs.
- Wear and tear on gearbox equipment can increase repair and replacement costs, potentially leading to a shorter operational lifetime compared to hydraulic motors (many gearboxes fail prematurely and contribute costs associated with production downtime).

HYDRAULIC DIRECT DRIVES: EFFICIENT AND EFFECTIVE

It can be seen that there are significant advantages to utilizing hydraulic direct drives for a growing range of applications. Currently, hydraulic-system providers offer a range of direct-drive hydraulic motors, typically rated by their RPM



For applications requiring higher torque than a single radial piston motor can offer, two or more hydraulic motors can be mounted in a tandem configuration, with a single hydraulic power unit configured to support the multiple motors.

capacity and torque capacity; they range from 2,000 Nm to 2 million Nm (the higher the torque, the lower the maximum RPM speed).

Selecting and configuring a hydraulic direct-drive system is based on the load and speed demands of a given application. Calculations to be considered include:
- The torque range that's required for both the starting values and operating values.
- The revolutions per minute that are required for the system's driven shaft.
- Total duty-cycle loads, frequency of start/stop conditions, and potential peak shock loads.
- These factors also govern the size of the fixed displacement motor, hydraulic fluid reservoir, and electric drive that will be chosen.

Hydraulic direct-drive systems offer a rugged, proven option for a range of low-speed high-torque applications. By being able to do more with less, they have proven to be highly efficient while providing essential high power densities. Simpler and more reliable compared to electromechanical drive systems with gear reduction, hydraulic direct-drive systems demonstrate a viable, cost-effective, long-term option for many of the most demanding transport and material-handling requirements. md

BRIAN BURKE | Product Manager
Bishop-Wisecarver Group

Five Heavy-Duty Gantry Alternatives

Save time and money with these five highly configurable products, all of which can be used in linear-motion-guided gantry configurations for factory-floor automation in place of high-cost multi-axis robots.

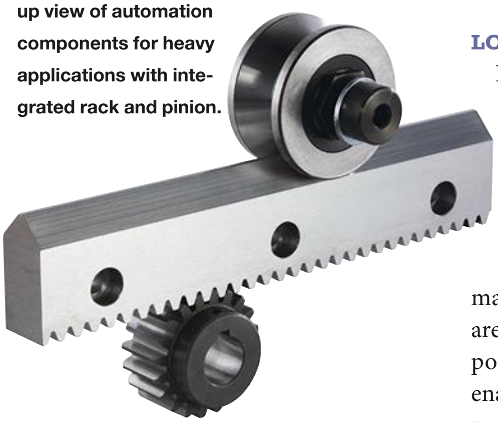
1. An example of a heavy-duty gantry based upon vee guide wheels with rack and pinion power transmission.

Automated motion-guidance systems with heavy-duty load capacities are experiencing a significant increase in demand. One reason for this revolves around the installation of flexible multi-axis robots onto long tracks. This allows engineers to greatly extend the work envelope while taking full advantage of a robot controller's seventh axis.

For many applications, a linear-motion-guided gantry system can accomplish the same tasks as a multi-axis robot while incurring less cost. Additionally, these gantry systems can be designed and supplied to end-users from standard heavy-duty subassemblies or components, and can be tailored to the specific application.

Here's a look at five highly configurable systems that can be used in gantry configurations for factory-floor automation in place of sophisticated robots. Let's start by reviewing some of the basic gantry concepts.

2. Pictured is a close-up view of automation components for heavy applications with integrated rack and pinion.



LOW TO MEDIUM PRECISION

Factory automation does not always require a high degree of precision. In many cases, the task involves heavy products and awkwardly shaped or off-balanced materials. Most applications require high repetition, extended operating time, and long-lasting durability with minimal maintenance. Frequently, the requirement for precision positioning is low *(Fig. 1)*.

Pick-and-place applications can require low precision when palletizing cases or placing the next item into the production queue. Material transfer applications may involve relocating products with an overhead robotic manipulator from one area to another. X-Y-Z gantry robots (the Z-axis refers to the vertical direction) can position and reposition materials anywhere within a three-dimensional space or enable operations on many faces of a work piece. Spraying systems may require low precision over long distances to paint a rail car or airplane wing.


BE THE HERO.
Pivot Point fastener innovations solve problems, saving time and money. Your application will love them, and you'll be an everyday hero.
SLIC PIN™
A pin and cotter all in one! US PAT: 6,872,039; 7,147,420. Foreign patents issued
BOW-TIE LOCKING COTTER™
Quick-locking cotter pin won't fall off! US PAT: 6,135,693 & D431,181
NYLON LANYARDS™
Low cost tether is an alternative to wire rope lanyards. US PAT: 5,784,760
RUE-RING LOCKING COTTER™
Our original design! Locking cotter pin offers two locking features!
AUTO-LOCK SAFETY PULL PIN
Our newest! The tip stays locked! US PAT: 8,821,061
OTHER SUPER POWERS INCLUDE:
WIRE ROPE LANYARDS
Per your imagination! Low cost, fast lead times.
QUICK RELEASE PINS
We're the experts in ball-detent technology!
WIRE LOCK PINS, LYNCH PINS
Many to choose from.
CLEVIS PINS
Carbon steel, alloy, stainless, aluminum and more.
BALL LOCK PINS
Push-button, dual ball security!
PUSH/PULL CONTROL CABLES
Unlimited Options
AND MORE!
POW!
• FREE SAMPLES
• STOCK & SPECIALS
• ENGINEERING ASSISTANCE
• COMPETITIVE PRICES
• FAST LEAD TIMES
PIVOT POINT
NON-THREADED FASTENER SOLUTIONS
Family-Owned, Hustisford, WI. 800-222-2231
WWW.PIVOTPINS.COM

3. Pictured is an X-Z gantry robot configuration designed for heavy pick-and-place applications.

HEAVY DUTY Z-AXIS

When moving a product, the first order of business is lifting that load. Great care is often taken in the design of end-effector grippers used for manipulating the product. A simple vertical lifting or lowering machine can be referred to as a Z-axis system *(Fig. 2)*.

After the item is lifted and supported by the system, all motion will generate additional loads due to accelerations of the mass. Significant loads may be generated during high-speed motion. Speed is typically determined based upon cycle time over the required distance. Loads are calculated based upon the acceleration (+ and –) of the mass. Speeds in typical gantries extend to 5 m/s.

Therefore, a heavy load capacity may be required to accommodate the expected motion. Additionally, a long service life can be designed into the application when working load requirements are a small ratio of the motion system's load capacity.

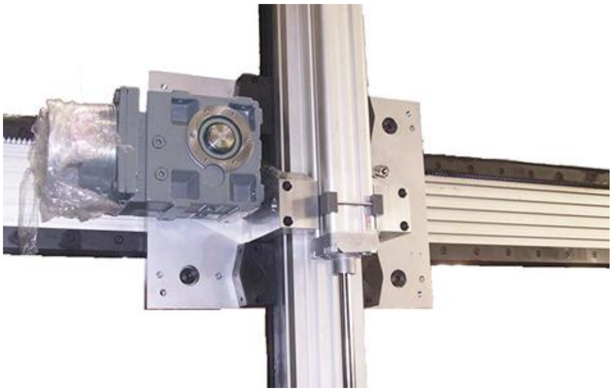
X-Z ROBOT OR X-Y-Z CARTESIAN

Single-axis motion stages can be combined with other positioners in various gantry configurations. Attaching additional motion systems adds reach and functionality, and tasks can be performed over longer distances.

X-Z robot: When a Z-axis linear-motion stage is mounted on an additional transverse axis of motion, it can be referred to as an X-Z robot. This configuration can lift an object vertically, move to another location in a straight line, and place the object there. This configuration is particularly useful for pick-and-place or transfer applications. The end of the X-Z robot can position and locate anywhere within a rectangular plane *(Fig. 3)*.

In some cases, the main mounting plate for the X-axis can hold the linear-guide bearings to the Z-axis and integrate all of the necessary pinion drive and automatic lubricator components. This greatly simplifies the design and reduces the overall moving mass *(Fig. 4)*.

X-Y-Z robot and X-X'-Y-Z robot gantry: The most flexible configuration of a robotic gantry system provides for three axes of motion to enable positioning anywhere within a three-dimensional work area. It is less common to have an X-Y-Z configuration because the axis attachment points become

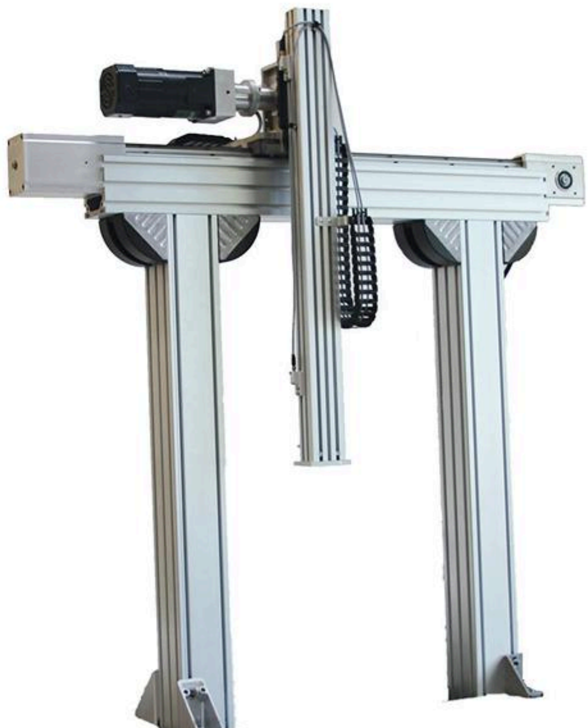


4. Shown here is a close-up view of a gantry carriage plate with bearings for two motion axes and an integrated gearbox.

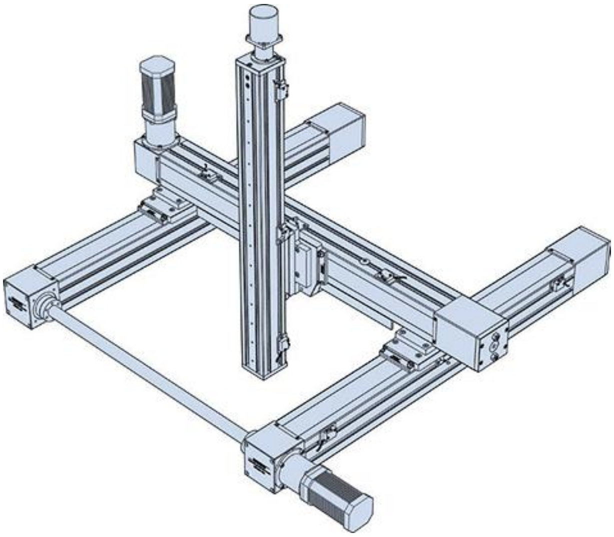
5. This is an X-X'-Y-Z gantry configuration for automotive assembly.

space constrained. However, this configuration is used extensively in automated welding where there are large travel reaches but no major loads. It is much more common to have a parallel X-axis solution where the Y-axis is supported on both ends. This configuration is called an X-X'-Y-Z gantry (pronounced X, X-prime). Examples of this configuration are easy to find in production machinery such as CNC routers *(Fig. 5)*.

Unlimited custom design configurations: There are many possible designs for a large-format automated motion system. A complete multi-axis X-Y-Z gantry robot can be custom designed



6. Shown is a belt-driven X-Z gantry with belt drives and cantilever Z-axis.



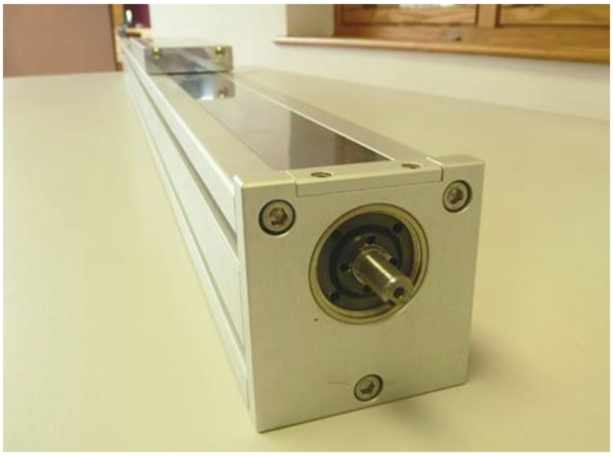
7. This is an illustration of a Cartesian robot made from ball screw actuators.

from the individual linear-guide rails and linear bearings, making it possible for engineers to select the best products for each area of the design.

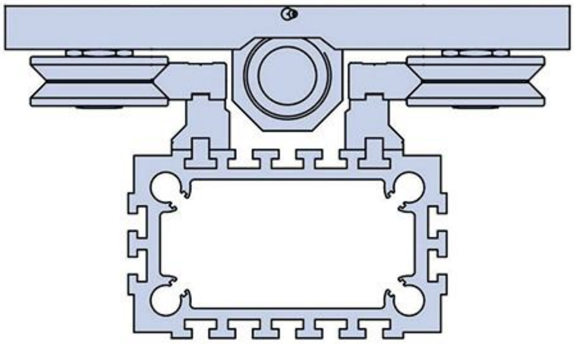
Existing product lines provide standardized components and subassemblies, which speed configuration and development by using common gantry layouts while providing the freedom to create a custom design. This is not possible with preconfigured or premade equipment that restricts work within previously established limits.

FIVE OPTIONS FOR GANTRY DESIGN

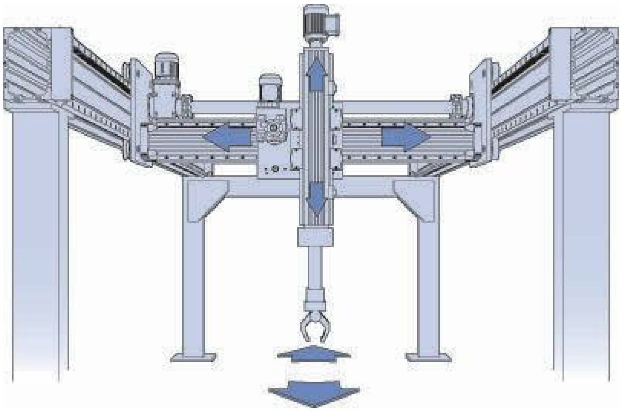
When designing automated machinery, it is usually best to start with a complete understanding of the required task and payload, the end-effector grippers that must be attached to the system, and an approximation of both the travel distances and



8. A close-up view of a ball screw actuator where the drive motor is attached.



9. The cross-section of a heavy-duty ball screw linear-motion assembly.



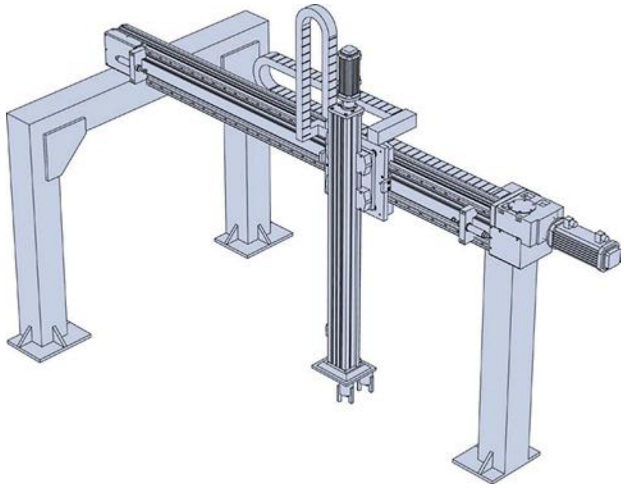
10. This illustration depicts a heavy-duty gantry installation with X-Y-Z positioning capabilities.

the speeds necessary during the travel. From there, the size and stroke length of the Z-axis can be determined followed by the other axes of travels.

The cantilever axis: A dedicated cantilever axis is a complete subassembly designed with the Z-axis application in mind. Linear actuator modules (those from Bishop-Wisecarver, for example) contain vee-guide wheel bearings running on a hardened and ground linear-guide track with power transmission provided by belts. They are available in a special version as a cantilever axis where the drive belt is stationary on the beam; it follows an omega shape around the motor pulley, which is attached in the middle.

When the motor turns the drive pulley, it moves the beam section of the linear-motion stage. This becomes an ideal configuration for the Z-axis of a gantry system because there can be simplified cable routings, and the motor does not contribute to the moving mass.

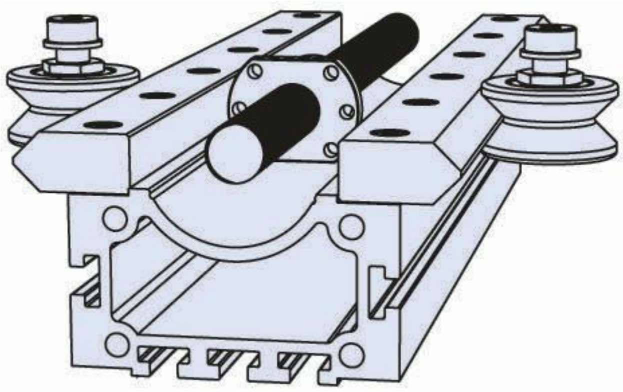
11. A heavy-duty compact ball screw actuator assembly.



12. This is a heavy-duty ball screw used as a Z-axis on an X-Z gantry configuration where the x-axis is a belt-driven actuator.

Another great feature of these actuator types is that the base is fabricated from T-slot aluminum, which can be readily attached to other motion axes or framing members. Although it is useful as a Z-axis linear module, these actuators have limited load capacity due to the belt system and the smaller size of linear bearings. These features make this product ideal for smaller loads and higher speeds, but it should not be considered for heavy loads *(Fig. 6)*.

The ballscrew actuator: Ballscrew-driven actuators are another type of complete subassembly for linear-motion stages that can be readily attached to other actuators in a variety of useful orientations. They are based upon similar actuator technologies and share the same key advantages, including the T-slot aluminum beam frames, internal linear profile rail bearing, stainless-steel cover strips with magnetic seal, internal travel bumpers, and simple gantry system attachment methods. The main difference from the belt-driven cantilever actuators is the use of a ballscrew as the drive technology. It enables the motor to be attached in a linear fashion above the



13. This is a cross-section of a heavy-duty compact beam ball screw actuator.

axis and provides substantial, efficient thrust capacities, which are well-suited for lifting and lowering heavy loads *(Fig. 7)*.

Ballscrew actuators are available in many standard sizes, with beam lengths up to 2,800 mm long. They are available with numerous ballscrew choices in a variety of diameters and lead pitches. A typical ballscrew actuator can handle loads up to 68,000 N radially mounted, but when mounted as a Z-axis, it has a maximum torque load capacity of 4215 Nm. Substantial life can be obtained from these product types up to 10,000 km of travel at 360 Nm *(Fig. 8)*.

The heavy-duty ballscrew system: These are preconfigured assemblies of components from a product line of heavy-duty linear guides. The preconfigured actuator system with an integrated ballscrew drive can handle up to 40,000 N radially, or in the gantry Z-axis position, 3220 Nm of torque moment load. They use large aluminum extrusions as the base structure for heavy-duty linear motion and include vee-guide wheel bearings and linear-guide track rails. These are available as individual components and subassemblies.

The aluminum beam of the heavy-duty system has many T-slots for attachment points. There are features in the cross-section that can be thread-tapped. Complete structures can be fabricated from this large aluminum beam. The vee-slide linear track is attached to the aluminum beam base and supported by an intermediate backplate extrusion. This assembly provides enough clearance for the ballscrew *(Fig. 9)*.

Heavy-duty ballscrew systems are available in standard sizes based upon the outside diameter size of the bearings as well as different precision grades, which includes commercial and precision versions. These grades refer the selection of linear-guide track. Both versions are made from high-carbon steel,

14. Shown is a carriage assembly with a drive motor and pinion.

which is surface-hardened for wear resistance. Commercial versions provide good accuracy and are etched on the wheel running surfaces. Precision versions are ground on the vee running surfaces and the mounting face to provide a greater level of accuracy *(Fig. 10)*.

The heavy-duty compact ballscrew system: The heavy-duty compact system is also a preconfigured ballscrew linear actuator. In contrast to the heavy-duty ballscrew system, the compact system uses a less gargantuan aluminum extrusion as the actuator base. The vee-slide carbon steel linear-guide track rail is directly attached to the beam without the need for a track backplate, and there is a recess in the profile shape to accommodate the ballscrew. Therefore, the overall height of the assembly can be significantly reduced. The beams can accommodate the same linear-guide track and bearings as the heavy duty ballscrew system *(Fig. 11)*.

15. Shown is an X-Z gantry for pick and place in a glass factory.

Heavy-duty compact ballscrew systems are available in standard sizes. The beam section with track can be up to 2,740 mm in length, but in some special cases the length can be as long as 5,840 mm. The vee-slide components are the same as those used in the heavy-duty ballscrew system, so there are different available grades of precision including commercial and precision versions.

There are also several choices of ballscrew pitches and leads. Because the same vee-guide bearings and vee-slide linear rails are used, these actuators share similar loading capacities with the heavy-duty ballscrew system; the units can accommodate up to 40,000 N radially. When they are used in a Z-axis gantry configuration, the load capacity can be up to 1,291 Nm *(Fig. 12)*.

The heavy-duty compact ballscrew actuator is an ideal size for most Z-axis vertical lifting operations and easily integrates with other motion stages. It can also be supplied with bellows style way covers to keep debris out of the slideway and ballscrew *(Fig. 13)*.

Customized Z-axis: There are many possible combinations when assembling the standard products into motion stages, and equipment builders have designed numerous variations. Many configurations of standard products have proven to be suitable for Z-axis motion stages.

This combination of products provides a reliable design and popularity among equipment builders has grown. A product line has not been formally created around this offering, such as is the case with the other products outlined, but the configuration is easy to specify.

The design starts with the compact aluminum beam used in the compact ballscrew configuration. Although it is labeled as a compact beam, the structure is quite large and suitable for Z-axis applications. Next, vee-slide linear-guide rails are attached directly to the aluminum beam. A version with machined gear rack teeth is used for the power transmission instead of a ballscrew or belts used by the other types of actuators. Only one of the vee slides requires the gear rack option to drive the actuator *(Fig. 14)*.

There are a few preconfigured carriage-plate assemblies with guide-wheel bearings and user attachment threads. The designer can select a carriage plate or specify his own design. A complete rack-driven carriage for the application can be supplied to make a complete driven Z-axis for heavy-duty applications.

BENEFITS OF USING HEAVY-DUTY COMPONENTS

Aluminum beam construction: T-slot based extruded aluminum beams are an ideal base material for gantry-mounted linear-motion systems. In many installations, the frame can be fabricated out of the same extrusion as the actuator. These materials can be quickly installed with basic tools at the installation location, and there are many brackets for attaching the extrusion. Additionally, these materials can be attached to welded steel support structures.

Linear guides with integrated racks: The time savings for using vee slides with the gear rack option cannot be overstated. Aligning a gear rack to a liner stage over a long travel length, in a heavy-duty application, can be a difficult and time-consuming task. Improper alignment will result in premature wear and low operational life. When the gear feature is integral to the vee-slide section, the alignment is taken care of because there is only one part to install *(Fig. 15)*.

System maintenance: It is not difficult to obtain the rated service life of a linear system when proper maintenance recommendations are followed. Lubrication is recommended for vee guide-wheel linear motion, so there are provisions for automatic lubrication. External track lubricators can be added to carriage assemblies, or there is the option of adding wheel cap wipers. In some cases, a maintenance technician can replace a single wheel bearing without a complete disassembly of the motion axis, and without removal of the cap wiper.

Load capacity and expected life. These products are capable of high loading conditions and can perform well in high-speed, high-cycle applications. Each design is validated with an expected life calculation so that the durability of the system is determined early in the design phase. If additional life is required, there is always the option for increasing the load capacity. Capacity is limited by the load rating of the bearings, along with the physical construction of the bearings. You could use larger bearings with more capacity, or change to a different type of bearing (e.g., going from a ball bearing to a roller bearing).

These five products are a small sample of the wide range of heavy-duty products that are available. However, the majority of Z-axis and multi-axis gantry applications would be satisfied by these recommend solutions. These products should be considered as a viable alternative for track-driven robots and gantry motion applications. md

STEPHEN MRAZ | Senior Editor
stephen.mraz@penton.com

Can FEA Test Sports Gear?

Engineers at Veryst dissected a host of golf balls to determine the composition of an average ball's core and many layers.

Researchers examine whether FEA can replace field testing for golf balls and other sports gear.

Tests of golf clubs and other sports equipment—whether carried out by their designers and manufacturers or the organizations that govern the various sports—take time and money. But could finite element analysis (FEA) replace all (or at least, most) of the testing currently done on sports gear? Would it give accurate results even when testing involved high-speed impacts, such as a golf club smacking a 200-yard drive, a bat hitting a home run, or a tennis racket serving a 100-mph ace? Those are some of the questions researchers at Veryst Engineering LLC outside of Boston were looking for in its recent simulation experiments and study of golf balls.

SETTING UP THE STUDY

Veryst engineers, with help from the U.S. Golf Association (USGA), decided to take a look at what current simulations and FEA could do in terms of accurately replicating the physical testing of golf balls.

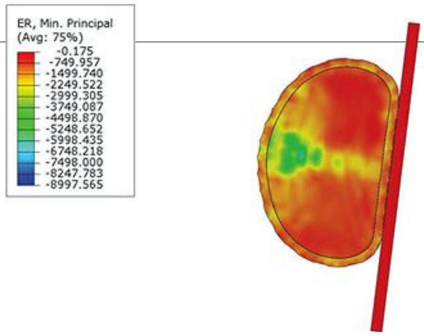
The USGA provided data it had collected from exhaustively testing a variety of balls. It had tested conventional balls—ones the average player would use, not expensive and exotic high-end varieties. USGA researchers used its golfing robot, Iron Byron, to consistently hit balls with the same force, velocity, and club-head angle at impact. They ran at least three series of tests using different types of club heads: one with a flat face, one with vee-shaped grooves, and one with round-bottomed grooves. They used high-speed cameras for each stroke and impact to measure the ball's speed and rate of spin or rotation. They also calculated how long the impact lasted (only a few milliseconds).

At Veryst, engineers were preparing to simulate that impact. The first step was to get an accurate and representative model of a golf ball—data the USGA did not have. So the team took core samples of several golf balls, dissected them, and then carried out a detailed engineering post-mortem. All of the balls were similarly constructed: a polymer core surrounded by several thin layers of plastic and other materials. They also shared a dimple pattern on the hard, white outer covering.

The team took thin, penny-sized samples of each material and put them through a few material tests. In one, samples were compressed relatively slowly compared to the speed at which the materials would get compressed in an actual impact. The samples were compressed until they reached a specified amount of deformation, with the test instrumentation recording the force involved.

In another test using a Split-Hotkinson pressure bar—also known as a Kolsky bar—large, fast impulse loads were applied to samples to get measurements of how the materials reacted and deformed. In this instrument, a sample is placed between two bars, a transmitted bar and an incident bar. A stress wave created at the end of the incident bar away from the sample travels quickly down that bar and toward the specimen, where it splits into two waves. One wave travels through the specimen and into the transmitted bar. The other wave gets reflected back up the incident bar. Strain gauges on both bars and the specimen measure changes in the strain waves as they pass through them. The strain data caused by the incident reflected, and the transmitted waves let technicians determine the stresses and strains in the specimen.

The vast majority of engineering schools and most companies lack this expensive research tool, according to Veryst. "But it's important to conduct such tests because materials react completely differently when loads are applied quickly rather than slowly," says Jorgen Bergstrom, a principal engineer at the firm. "In fact, results from the Split-Hotkinson tests showed that many materials in the golf-ball cover behave nonlinearly



FEA results show how strain rates vary throughout the ball upon impact, with blue representing the lowest strain rate and red the highest.

in response to forces when they are applied very fast.

"Many engineers are unaware that the materials used in some of the layers of the golf ball behave extraordinarily different at high impact velocities than they do to slow ones," Bergstrom continues. "So if they carried out conventional mechanical testing, which is done relatively slowly compared to an impact, they could mistakenly assume that is how the material will behave in fast impact events. In fact, material properties can differ by a factor of 10 from what the slow-rate data would indicate. It takes insight to realize this or experiments to verify it."

For impacts, Bergstrom says a slow-rate event takes seconds to complete, while a fast-rate event ends in a few milliseconds.

The project would also require good models of the three types of club heads. The engineers determined that the head was much stiffer than the ball, and that deformation would affect the ball to a much higher degree than the head. This let the researchers concentrate on the shape of the club head and the pattern of grooves, simplifying the model of the head.

"We did not try to evaluate or include grooves of different sizes or shapes or the spacing between them," notes Bergstrom. "We focused our efforts on modeling the ball and just the shape and grooves of the head."

PROVING THE MODELS

With material data in hand, Veryst began modeling the two components for the simulation. For the head, they used straightforward CAD software. But for the ball, they relied on used Python scripting software that could automatically mesh the model for FEA.

"The ball's geometry is simple: a series of spherical shells of different materials," says Bergstrom. "The challenge with the ball, however, was its outside surface. It contains several hundred dimples that determine the ball's aerodynamics. But how the ball sails through the air after it is hit was not an area of interest for our study. We wanted to ensure we looked at the entire impact event and how the club interacted with the ball's surface, so we had to include the ball's surface geometry."

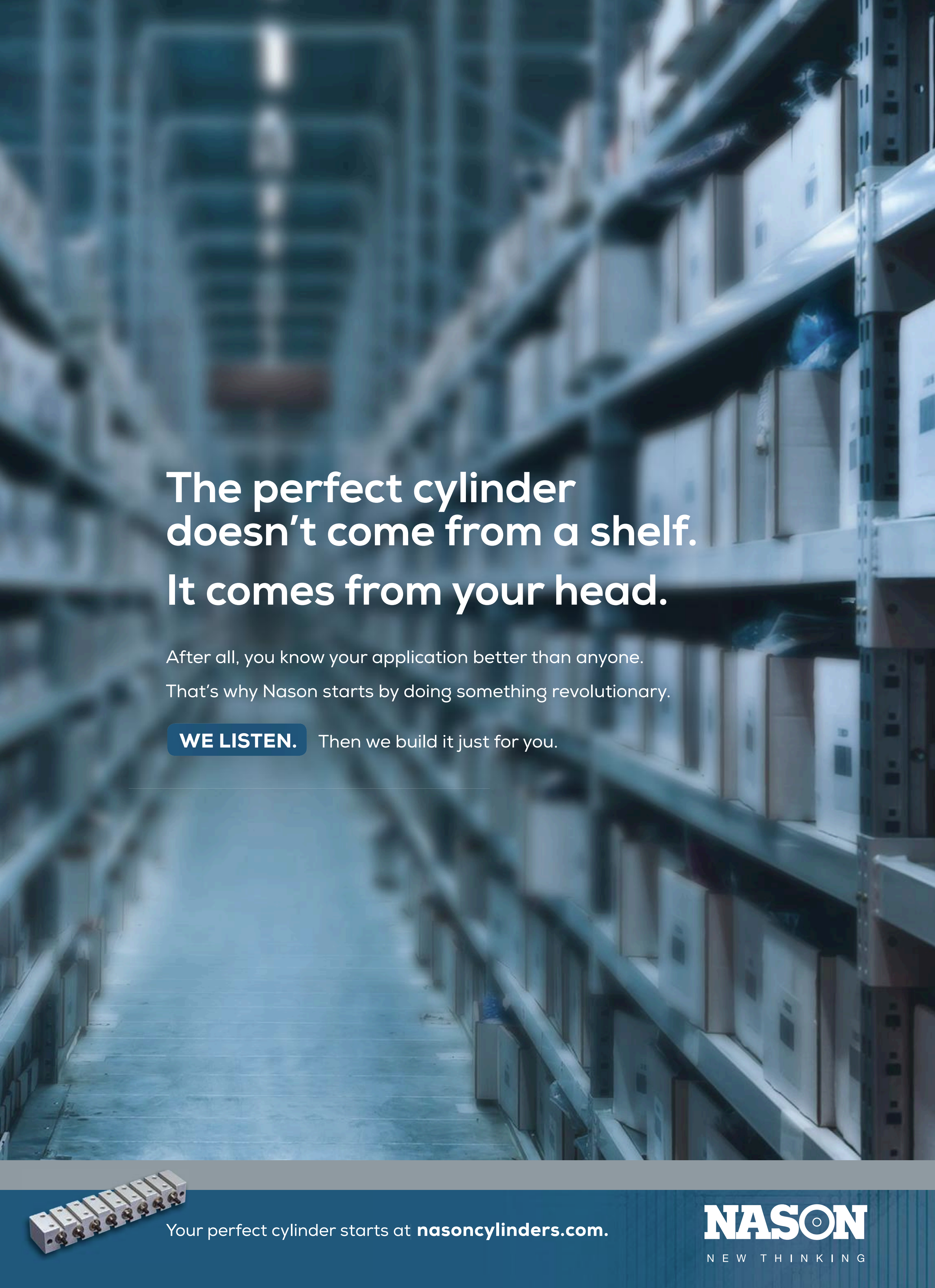
The Python software let the team quickly create a mesh and easily alter the model and surface pattern. So in the future, others can look at whether it makes a difference on ball speed and rotation if the dimples are larger or smaller, or closer or father apart.

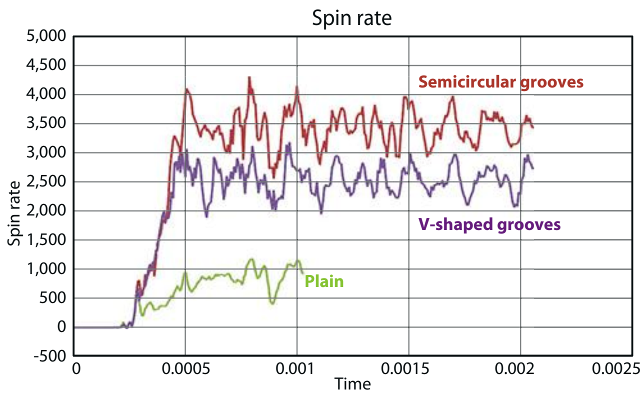
To ensure the mesh was not too coarse, which would mean the results were not valid, or not too fine, thus leading to excessively long run times for the FEA software, a mesh refinement study was carried out. It starts with a coarse mesh, and finer meshes are used in flowing FEA runs. When additional fineness, which translates into ever smaller elements, does not change the results significantly, the mesh is considered optimal.

RUNNING THE ANALYSIS

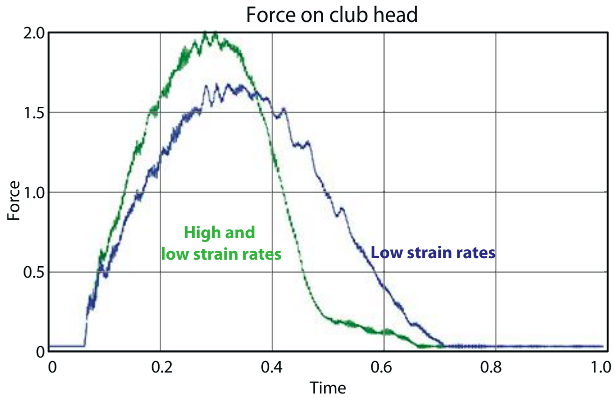
With the models and mesh in place and the actual results from the USGA in hand, Veryst ran the impact simulations. But because the impact event was quick and the ball's materials did not react linearly during testing, the team decided to use more than one type of modeling program.

"Engineers might assume that in the impact between a golf ball and club, the material in the ball deforms uniformly, but that is not the case," notes Bergstrom. "Some regions of the ball


The perfect cylinder doesn't come from a shelf.
It comes from your head.
After all, you know your application better than anyone.
That's why Nason starts by doing something revolutionary.
WE LISTEN. Then we build it just for you.
Your perfect cylinder starts at nasoncylinders.com.
NASON
NEW THINKING



A graph of ball spin rates versus time derived from simulation data indicates that the U-shaped grooves on the club face (red) impart a bit more spin than the V-shaped grooves (purple), and much more than a plain flat club face (green).

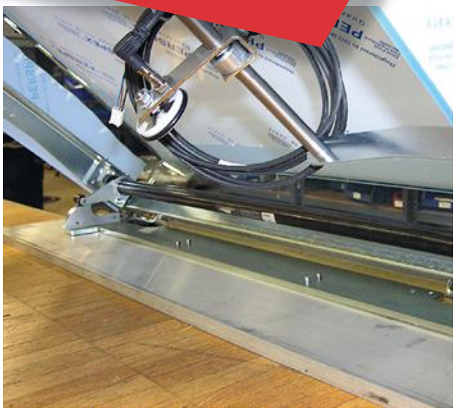


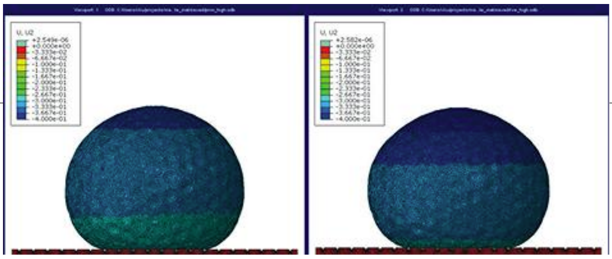
To see how sensitive the model's results for force on the club head during impact as a function of time were to strain rate, the team simulated the force using high and low strain rates (green curve) and compared them to results from using just low strain rates (blue).

will experience more deformation and strain than others. So even if the actual duration of the impact is short, the range of deformation and strain rates will vary throughout the ball. The key is to have a model that captures the influence of how different strain rates influence the ball's response."

The team decided to use the linear viscoelastic model (LVE) and the parallel network model (PNM). LVE is a simplified model that recreates a materials viscoelastic behavior by modeling it as a network of springs and dampers. One drawback of the LVE is that the deformation and strain, as well as their rates of change, must remain in a relatively narrow range. If they do not, then the material response to the impact is nonlinear.

"This makes LVE often good enough for experiments," says Bergstrom. "But it is not as good or accurate with nonlinear





These two images show contours of vertical displacement during simulation of impact. The figure on the left shows results from a non-linear viscoelastic parallel network model, and the figure on the right shows results from a simple linear viscoelastic model.

events and those that happen very quickly." The team also ran the simulation using a parallel network model (PNM). It recreates a material's behavior using a similar network of springs and dampers, but they have nonlinear responses. This lets them recreate highly nonlinear plastic behaviors.

The PNM can provide exceptionally accurate predictions of the behavior of material models, even if those materials are anisotropic viscoelastic polymers. The model's main limitation is that it can take some time for an engineer to fully understand how best to structure it for a new material. PNMs also take more time and effort to set up and run because they require accurate information on strain rates at different levels of deformation, and this means more data gathering.

In this study, using PNM meant Bergstrom had to reverse-engineer the ball and determine the composition and properties of each layer. "But once you do the reverse engineering," says Bergstrom, "you have all the data you need to carry out a long list of other experiments and simulations."

RESULTS AND CONCLUSIONS

Data from the PNM simulations matched the USGA experimental data quite closely. The LVE results also mirrored the experimental data, but were much less accurate than the PNM data.

"Our study seem to indicate that computerized models, simulation, and FEA—or virtual testing—will let engineers cut corners in investigating some material-behavior issues," says Bergstrom. "For example, it can eliminate some physical testing, which saves money and time. It also gives designers a powerful tool that will let them investigate all kinds of parameters. We just scratched the surface in this study. We could use the information we have to look more closely at club head, club design, or club head velocity."

Virtual testing could also give engineers insights into parameters and phenomena that are hard to measure experimentally.

"For example, what if a designer wanted to know how much energy is dissipated during the impact between ball and club?," asks Bergstrom. "That is hard to measure in actual experiments because energy dissipates in several forms, and ball covers behave nonlinearly. But we can get that data directly from simulations like this one." md

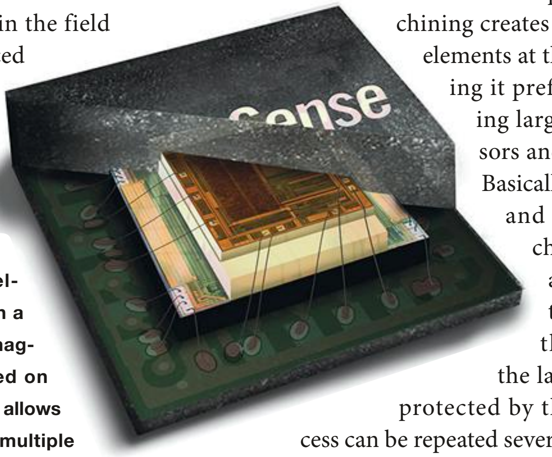
JEFF KERNS | Technology Editor

Practical Tips for Specifying Sensors

Experts in the industry talk about common concerns when considering sensors.

The environment acting to our whim has been seen in entertainment and may have actually influenced the development of some of today's inventions. Such science fiction turned into reality due to the ability of electronics to work with the natural world. However, concerns arise when trying to find the right sensor to detect this world. The following background discussion on sensor manufacturing and a Q&A with experts in the field offers a glimpse into the common issues experienced in the sensor industry.

Special thanks to Ian Chen, executive of Freescale's Sensor Solution Division; Mark Howard, general manager for Zettlex; Tom Curl, managing director at ENERTEX; and Hauke Dierksheide, marketing engineer for First Sensor AG, for shedding some light on common concerns about sensors.



A gyroscope and accelerometer are printed on a single die, and then a magnetometer is assembled on the back of the die. This allows one package to detect multiple forces in the physical environment. Sensor packages can reduce size and cost while offering more features. *(Credit: Invensense.com)*

MANUFACTURING

Advances in micromachining and other techniques are generating microstructures that help create more complex sensors with expanded abilities. Processes that foster these complexities and abilities, yet still enable sensors to be mass-produced and economical, are essential to the electronics consumer market.

Consider STMicroelectronics' approach as one case in point. Over the last decade, the company geared itself toward high-volume production with a surface micromachining technique that showed how integrating a sensor, or several, can add more value to a product than the cost of the sensor itself. In general, surface micromachining alternates thin films, often polysilicon and silicon dioxide layered in specific ways. Therefore, when the silicon-dioxide layers, also called the sacrificial layers, are removed by the etchant, it's possible to leave freestanding structures.

Microelectromechanical-system (MEMS) production is the most common application of the micromachining process. The bulk-method process of micromachining creates multiple electronic elements at the same time, making it preferable for producing larger volumes of sensors and other electronics. Basically, a wafer is masked and then exposed to a chemical etchant for a specific period of time. At this point, the method etches the layer of material not protected by the mask. The process can be repeated several times to form the complex geometries, strategically layer by layer, leading to more powerful sensors.

Electronics may seem synonymous with silicon, but transducers can also be fabricated using metals, glass, and even polymers. Certain inherent roadblocks exist with silicon, but its properties, the tremendous wealth of knowledge about the material, the refined processes for production, and low cost create an inertia that will no doubt keep silicon around for decades to come.

But Zettlex's Howard predicts that current silicon technology may become less common in high-end devices over the next 10 to 15 years. New materials and hybrids of silicon under development target harsh environments with extreme temperatures and vibrations. Eventually, lower production costs will permit entry to the consumer market.

Wafer bonding—building up of material layers—is another interesting process. Two popular methods involve bonding silicon to silicon or silicon to glass. Technicians can build up layers to team up with micromachining and other processes to add more features to components. This bonding process can also be used to protect an electronic element by adding a layer that seals the unit from the outside environment. Ultimately, it might aid in higher-volume MEMS processing versus current production approaches, and become a driving technology in producing complex forms of electronics.

MECHANICAL MEASUREMENTS

Measurement	Common techniques	Measurement	Common techniques
Displacement/ position	Variable reluctance, Hall effect, optoelectrical	Flow	Delta pressure
Temperature	Thermistor, transistor V_{be}, thermocouple, infrared (IR)	Humidity	Resistive, capacitive
Pressure	Piezoresistive, capacitive	Proximity	Ultrasonic
Velocity (linear/angular)	Variable reluctance, Hall effect, optoelectrical	Range	Radar, LIDAR (light detection and ranging)
Acceleration	Piezoresistive, capacitive, piezoelectric	Liquid level	Ultrasonic
Force	Piezoresistive	Slip	Dual torque
Torque	Optoelectrical	Imminent collision	Radar
Mechanical impedance	Piezoresistive	Touch	Capacitive, resistive, inductive
Strain	Piezoresistive		

This table shows what techniques can be used to find a desired measurement. Understanding these techniques is key to reducing problems down the road. *(Credit: Understanding Smart Sensors, 3rd Edition by Randy Frank, published by Artech House)*

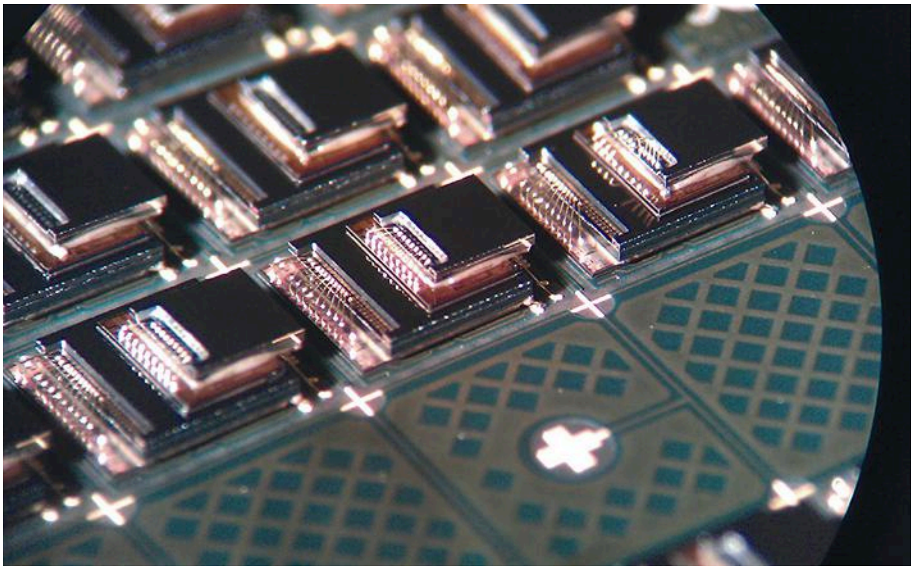
SENSORS TODAY

Research into designs and processes are helping expand the sensor's capabilities. The Internet of Things (IoT) and machine-to-machine (M2M) communications are just two examples of the growing demand for electronics that can communicate with the physical world. We asked the experts which technologies we should watch and which were, or might be, game changers.

Freescale's Chen said, "I have been working in semiconductors and high technology since the late 1980s. I first ran into MEMS in the early 2000s. I would say the continued improvements of size, performance, and cost for MEMS sensors is the biggest advancement I have seen."

Sometimes the technology isn't in the sensor itself, but how it is designed. Reducing cost and streamlining the process is also important. Howard talked about his 30-year career as an engineer, and some of the bigger advances he has seen during that experience.

"Computer-aided drafting (CAD) is giving designers and engineers the ability to build and even test sensors before cutting any metal. This software is greatly helping to save time and improve sensor quality," he said. "2D and 3D printing are technologies to watch. Giving people the ability to pro-



Surface micromachining can build up multiple layers for complex features.

duce low-power, low-cost, miniature integrated circuits, from designing them or adding them into a system from a library and then printing the technology off of a desktop printer, will be a quantum shift."

The sensor industry is large and many technologies are affecting different markets. When we asked Curl of ENERTEX which technologies are leading the industry, he answered, "The answer depends on the industry. Microfluidics in biomedical, MEMS in mechanics/physics, magnetic sensors in machinery, lasers for measurement, carbon nanotube for chemicals, the list can go on and on."

Many wonder how far electronics will go in terms of power, and what types of features they will possess. Right now, there don't seem to be any limitations on the electronics and sensor industries as innovations continue unabated. With the IoT, M2M, and wearables, modern electronics can give us applications we might not have thought were possible just five or 10 years ago. Regardless, it's essential to specify the best sensor for a job. Here are four tips for getting it right:

SELECT THE RIGHT SPECS

Matching demands of an application to properties of a sensor might sound simple enough, and sometimes that's the case. Sensors cover a wide scope of possibilities, but the more an engineer knows about the process and the types of available sensors, the more equipped he or she is to design a system.

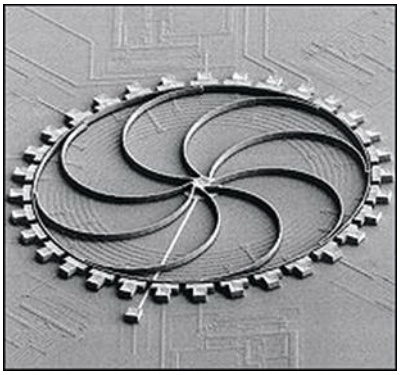
Basic options focus on aligning the product to the nature of the application. Basic properties to look for will change with different sensors, but may include price, size, supply voltage, output signal, and media compatibility.

The first step in this scenario is to match the product's properties with the application's demands on the sensor, which helps ensure that the sensor can capture the required signal. The second step is to consider the right technology in the right environment, with the idea of a cradle-to-grave lifespan assigned to the product. According to Chen, "More experienced designers might ask about the bandwidth, linearity, and

temperature coefficients of a sensor to match their application requirements."

The sensing industry is rapidly changing, allowing different features to be used in multiple applications. Curl explained, "Early in my career, starting in 1960, detecting if a cooling fan was operational employed a 'vane switch.' This was a Microswitch with a thin flat plate facing the vane actuated by the airflow. Later, the job was done optically with LEDs and photodiodes.

"Today, most cooling fans include built-in magnetic speed sensors to accurately report the rotational speed of the fan," he continued. "The challenge is trying to find sensors reflecting modern technology at an acceptable cost. This can be difficult in a fast-moving industry, as there is almost always something a little better just around the corner."



Micromachining helps create complex geometries that allow for small sensors, such as the one shown, to handle multiple jobs. This ring angular rate sensor from Delphi is used for automotive steering assistance, active brake control, and rollover detection. Production sensors are vacuum-sealed using wafer-to-wafer bonding.

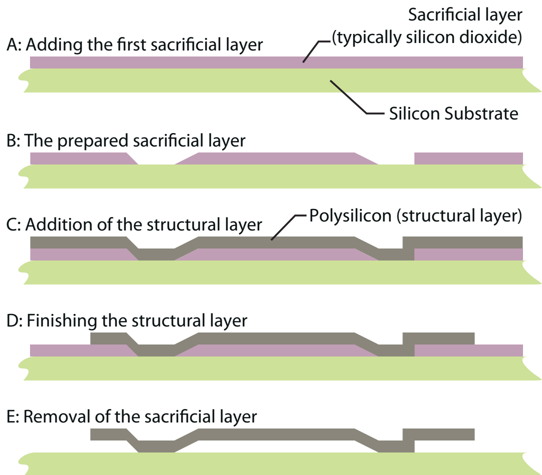
(Credit: Delphi-Delco Electronic Systems)

FIND THE RIGHT SIGNAL

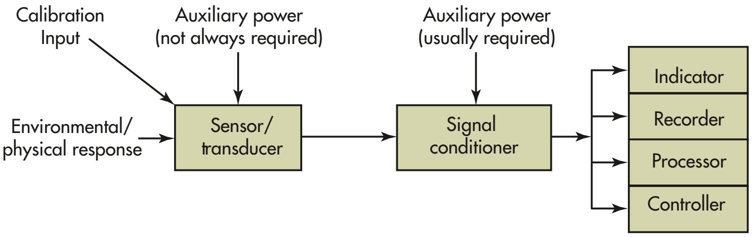
Understanding the technology behind how a sensor works can save problems downstream in the manufacturing process, and save time in troubleshooting a system.

"Probably the most interesting challenge in using sensors is to understand what environmental factors will affect the sensor's readings," said Chen. "The sensor is measuring the physical world, so it will pick up all the noise in the environment. For example, an accelerometer will also measure gravity. An altimeter will also pick up atmospheric pressure. Pressure is dynamic, changing due to weather. Sensors are very powerful and contain a lot of information, so to distinguish the difference is the most important piece of the puzzle."

Sensors are sensitive and susceptible to drift. Properly calibrating the sensor and monitoring electronic components over time is necessary to ensure continued accurate readings. Drift can be caused by the degradation of the



By alternating thin films, often polysilicon and silicon dioxide (sacrificial layers), surface micromachining can produce complex features that may be impossible to do with other processes.



Today's sensor or sensor package tends to be much more complex than this general sensing system. Monolithic designs can house multiple sensors in one package. *(Credit: Understanding Smart Sensors, 3rd Edition by Randy Frank, published by Artech House)*

sensor's materials, overuse, and abuse. Customers may not understand the importance of calibration. Manufacturers test and calibrate the sensor, initially, in a closed environment to achieve desired specifications. Once the sensor is in a changed environment, it must be recalibrated.

"The act of soldering a sensor into a circuit can shift the transducer's offset because it creates a stress the sensor can detect," said Chen. "The sensor must be calibrated after it is soldered or an algorithm used to negate the offset."

Once calibrated, the noise or other signals the sensor might detect in the environment must be considered. Designers often reduce noise with signal processing. In one type of signal processing, the first-order derivative from the input signal is recorded and then examined as to how it changes over time. As a result, filters can be added as part of the signal processing to reduce the amount of noise that proceeds to the next step.

Sensor fusion offers another way to reduce noise, and add features. Sensor fusion reduces noise by combining data collected from multiple observers (multiple sensors), and then uses algorithms to compare the data and filter out noise. This technique helps detect the signal desired by the end user, keeping in mind that the end user might be another program, sensor, or machine.

Understanding the types of measurements performed by the sensor helps engineers select the right sensor for the given job at hand. Considering how the sensor measures the environment can also facilitate electronics troubleshooting for technicians.

Nikola Tesla said, "If you want to find the secrets of the universe, think in terms of energy, frequency, and vibration." Sensors are how engineers are communicating with those energies, frequencies, and vibrations. One could say that the better people communicate with the universe, the more out of this world our innovation in electronics can become.

CONSIDER ENVIRONMENT

Environmental concerns aren't always apparent. Failures have happened to electronics along coastal areas, when components sensitive to salt were not sealed or replaced with a technology that better handles humid or salty air. Howard said, "It is important to select the most appropriate technology for the application. For example, make sure you're not putting an optical sensor in a dirty environment where it will get covered in oil and stop working, or a potentiometer in a high-vibration environment where it will wear out after a day."

Selecting the right sensor that can do the job is foremost, but thinking about the sensor's capabilities in a particular environment is crucial, too. Selecting inappropriate devices could cost companies upwards of millions of dollars from mistakes that, in hindsight, seemed elementary. However, when designing in a controlled environment,

it may take an extra step to consider what might seem obvious.

CONSIDER COST

The bottom line is important in any part of a design. When thinking in terms of mass production of a product, reducing the cost of a single sensor could significantly shrink production costs. However, it's important to remember that selecting a cheap sensor versus a cost-effective device could wind up hurting the company's reputation and profit margins.

"First, understand the nature of the application," said Howard. "In other words, a solid requirements spec. Second, match the spec to the most appropriate sensor technology. The most frequent question is 'How much does a sensor cost?' It is disappointing. Often focusing on a low-cost sensor will result in much higher costs in the end. 'Most appropriate technology' means least overall cost; taking everything into consideration, not just the sticker price."

However, processes like micromachining have had a huge impact on both size and cost. "MEM-based gyros, for example, have replaced spinning mechanical devices, costing hundreds even thousands of dollars with devices costing less than a dollar and having even greater accuracy," said Curl.

In another example, engineers are using sensor fusion with multiple microphones to determine a sound's origin. This technology means your smartphone could eventually work with an app to replace hundreds of dollars of audio equipment.

Reducing cost largely relates to the mass production of sensors and other electronic components. Manufacturing and the market have allowed for this level of production. With all of the available software and platforms, sensor applications are on the rise. And the processes and designs for them, right now, look like they will continue offering more for less. md

CARLOS M. GONZALEZ | Technology Editor
carlos.gonzalez@penton.com

A CLOSER LOOK at Motors for Motion

Several differentiating factors influence the choice of motor for robotics, medical, packaging, and other motion-control applications.

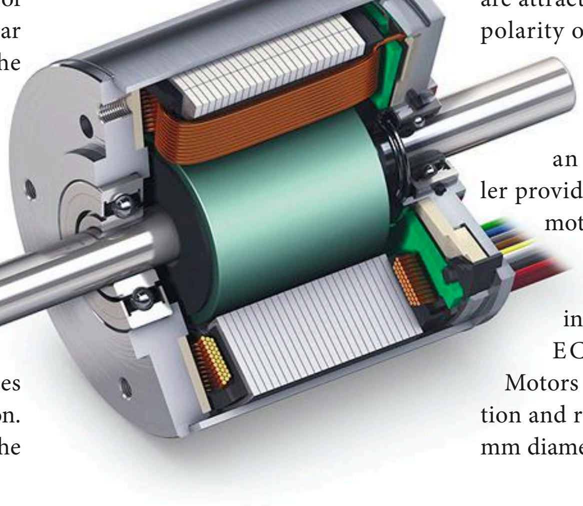
Motors play key roles in many motion-control functions across a multitude of industries, from packaging, food and beverage, and manufacturing to medical and robotics. Engineers can choose from several motor types, depending on function, size, torque, accuracy, and speed requirements.

DC MOTORS

Direct-current (dc) motors tend to have a low torque unless they are paired with a gearbox. A gearbox will decrease the motor's speed and increase the torque output. If a dc motor, for example, rotates at 10,000 rpm and produces a torque of 0.001 N-m (0.0089 lbf-in), its torque can be increased by a factor of 300 by attaching a gearbox with a gear down ratio of 300:1. This reduces the rpm to 33.3 rpm and increases the torque to 0.3 N-m (2.66 lbf-in).

A brush dc motor functions with two magnets facing the same direction around a rotor. They surround two coils of wire in the middle of the motor. The coils are positioned facing the magnets, causing electricity to flow. The magnetic field that's generated pushes the coils away and causes rotor rotation. The carbon brushes, located inside the rotor, conduct current between stationary wires and moving parts. They are attached via rings to the rotor's shaft, which are connected to an electrical circuit. Rotation speed is proportional to the applied voltage. Brush dc motors, with their simple construction, offer a cost-effective solution.

Maxon Precision Motors *(www.maxonmotorusa.com)* added four new sizes to its Maxon X Drive family of brushed dc motors *(above, right)*. The three-stage motors are now available in 14-, 16-, 22-, and 26-mm-long diameters. These motors offer high continuous torque and power. They range in rpm from 7,720 to 11,600 rpm and 4.11 to 132 mN-m.



Along with these motors, Maxon introduced new GPX planetary gearheads, which have scaled-gear advantages. The drive system is smaller, lighter, and more economical. The gearheads come in 14-, 19-, 26-, and 37-mm diameters. The existing GPX 16 and 32 models are now available with ceramic axles. These will reduce wear and lower gearhead noise.

Brushless dc motors don't contain carbon brushes. Rather, they have permanent magnet poles on the rotor that are attracted to the opposite magnetic polarity of the rotating poles located on the stator. This creates torque and instead of brushes providing the dc current, an electronic speed controller provides the current. Brushless dc motors require less maintenance, generate less noise, and create less electromagnetic interference (EMI).

EC-i motors from Maxon Motors *(left)* are suited for automation and robotics. These compact (40-mm diameter) options offer simultane-

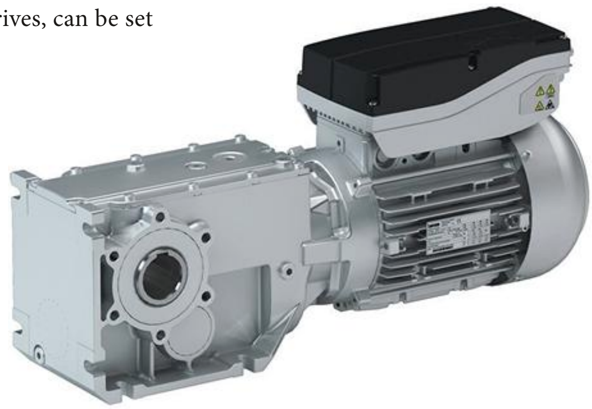
ous high energy and torque, and come in two length sizes. The 26-mm length offers 12,400 rpm with 43.2 mN-m or 13,200 rpm with 52.7 mN-m. The 36-mm length maintains 10,100 rpm with 68.4 mN-m or 10,700 with 82.9 mN-m. They have low inertia of 10.5 g-cm^2, are robust, ensure high power density, and offer maximum drive in minimum space requirements.

AC SERVO MOTORS

Alternate-current (ac) motors, which function like brushless motors, target applications that require rapid and accurate response. Their design has small diameters and high resistance rotors, thus providing low inertia for fast starts and stops.

The N-Servo ac brushless servo motors *(right)* from Baldor *(www.baldor.com)* provide a design with neodymium-iron-boron magnets. Continuous stall torque ranges from 0.45 to 40 N-m, and acceleration torque from 1.8 to 160 N-m. The servo motors are 200°C moisture-resistant and designed to operate in temperatures up to 155°C. Their inertia range, 0.067 to 38 Kg-cm^2, is low to attain high acceleration capability. The servo motors are not only common in robotics, but also medical, packaging, and manufacturing industries.

The Lenze Smart ac motor *(www.lenze.com/en)* delivers near-field communications (NFC) for smartphone controllability *(below)*. It features three digital inputs for changing speed and motor rotation and one digital output for status readings. The easily adjustable speed, which reduces the required number of different drives, can be set



between 500 and 2,600 rpm. It has a higher starting torque than continuous torque, as well as being compact and energy-efficient. Max torque ranges from 7 to 20 N-m.

STEPPER MOTORS

Stepper motors achieve mechanical movement through digital pulses instead of continuous voltage. They rotate or step in fixed angular increments. A pulse generator communicates with the stepper driver, which controls speed and positioning. With each control pulse, the stepper motor and driver convert digital information into exact rotational steps.

Lin Engineering *(www.linengineering.com)* released the new Whisper Torque ZH417-11 hollow-shaft stepper motor. It is a 0.9°, NEMA 17 stepper motor with an 11-mm inner diameter *(left)*. Instead of a magnet on the rotor, it features a ring magnet around the stator coils. Without the permanent magnet, large shaft dimensions can be implemented, since only the outer edges of the rotor are used. The motor maintains a holding torque of 0.12 N-m and an inertia of 21.9 g-cm^2.

Haydon Kerk (www.haydonkerk.com) offers a family of ac can-stack stepper-motor linear actuators *(below)*. Stepper-motor linear actuators use the stepping motor for rotary power, but replace the shaft of the rotor with a lead screw. Linear motion occurs as the rotor turns and advances the nut and threaded screw. A small rotation force on the lead screw can translate into a large load capability, depending on the thread lead. A smaller thread lead (or more threads per inch) will provide a higher force, and a large thread lead has a lower force with a higher linear speed. Five basic frame sizes are available: 15, 20, 26, 36, and 46 mm in diameter. They operate with a torque range of 0.4 to 1.8 N-cm; the linear actuator has a force range of 8 to 191 N. The stepping motors are available in 300- or 600-rpm options. md

distribution resource

from global purchasing
globalpurchasing.com

VICTORIA FRAZA KICKHAM | DISTRIBUTION EDITOR victoria.kickham@penton.com

Image courtesy of Thinkstock

Electromechanical Solutions Improve Factory Automation

As OEMs and others seek new and better electromechanical systems, specialty suppliers step up their knowledge and offer hands-on solutions that streamline processes and improve operations.

JOE NOWLAN | CONTRIBUTING EDITOR jcnowlan@gmail.com

AS INNOVATIONS EMERGE IN electromechanical technology, distributors are on the front lines providing services that streamline manufacturing processes and help conserve energy. The growing use of electromechanical actuators is a case in point. When such systems are used in the handling and delivery of a package by UPS, FedEx, or the U.S. Postal Service, the innovation becomes clear.

That package that arrives at your home with a dent or hole in it? It's not necessarily the fault of someone at your post office or a clumsy delivery driver, explained Bob Yager, automation manager at Gulf Controls Company Inc., a specialty distributor based in Tampa, Fla.

Frequently, that damage occurs somewhere on a conveyor belt that is

Continued on Page 82

Global Purchasing's 2015 Top 50

The industry's largest suppliers of electronic components cite successful 2014, point to positive outlook for 2015.

GLOBAL PURCHASING is proud to publish its fifth annual *Top 50 Electronics Distributors* list, compiled from nomination forms submitted during February and March from suppliers of electronic components and related items. Each company in our list is ranked according to its total global sales volume, and all figures are reported in U.S. dollars. We used self-reported data from each company and verified the information against annual reports and earnings statements, where possible, as well as in follow-up interviews with some of the companies at the top of the list.

In general, the distributors on our list said they had a strong 2014 and that they look forward to another good year in 2015. On average, the top 10 returning companies to our list reported a 7.5% sales increase. Here are the details on this year's Top 50:

Figures for Avnet Inc., ranked first, and Arrow Electronics, ranked second, include the sale of computer products, which comprise large seg-

Continued on Page 80

ments of each company's business. The ranking for privately held Future Electronics, fourth, is based on a *Global Purchasing* estimate.

Figures for Allied Electronics, sixth, reflect its worldwide sales as part of UK-based Electrocomponents plc, which also operates RS Components in Europe. The figure here is a company-provided, fiscal-year 2015 estimate for global sales. Likewise, sales for ninth-ranked Newark element14 reflect worldwide sales as part of its parent company, Britain-based Premier Farnell.

There are some changes to this year's list based on newcomers to the survey and our efforts to make the list more global each year. Macnica Inc. debuts at No. 5 with $3.4 billion in worldwide sales. The Japanese company was established in 1972 and opened its U.S. business, Macnica Americas, in 1995, based in California. North American sales represent about 17% of the company's business. The company's entry caused a shift in the top 10, with Electrocomponents/Allied, TTI, Digi-Key, Newark/element14, and Mouser moving down one spot each to occupy the six-through-10 spots.

German distributor Rutronik Elektronische Bauelemente GmbH enters our report at No. 11, with global sales of $810

Continued on Page 87

global purchasing — 2015 TOP 50 ELECTRONICS DISTRIBUTORS — distribution resource

Company	2014 global revenue
1. AVNET INC.[1]	$28.1 billion
2. ARROW ELECTRONICS[2]	$22.8 billion
3. WPG HOLDINGS LTD.	$14.9 billion
4. FUTURE ELECTRONICS[3]	N/A
5. MACNICA INC.	$3.4 billion
6. ELECTROCOMPONENTS PLC/ALLIED ELECTRONICS[4]	$2.11 billion
7. TTI INC.	$1.95 billion
8. DIGI-KEY CORP.	$1.76 billion
9. NEWARK/ELEMENT14[5]	$1.6 billion
10. MOUSER ELECTRONICS	$907 million
11. RUTRONIK ELEKTRONISCHE BAUELEMENTE GmbH	$810 million
12. N.F. SMITH & ASSOCIATES	$747 million
13. DAC/HEILIND	$715.7 million
14. FUSION WORLDWIDE	$318 million
15. AMERICA II ELECTRONICS	$250 million
16. SAGER ELECTRONICS	$227 million
17. PEI-GENESIS	$212 million
18. MASTER ELECTRONICS	$175 million
19. REBOUND TECHNOLOGY GROUP HOLDINGS LTD.	$161.5 million
20. BISCO INDUSTRIES INC.	$136.8 million
21. POWELL ELECTRONICS	$120 million
22. CLASSIC COMPONENTS CORP.	$103 million
23. FLAME ENTERPRISES	$100.7 million
24. ELECTRO ENTERPRISES INC.	$82.5 million
25. STEVEN ENGINEERING INC.	$73.6 million
26. RFMW LTD.	$72 million
27. BEYOND COMPONENTS INC.	$70 million
28. HUGHES PETERS	$69.7 million
29. PHOENICS ELECTRONICS	$61 million
30. SYMMETRY ELECTRONICS CORP.	$57.5 million
31. EDGE ELECTRONICS	$47 million
32. MARSH ELECTRONICS	$45.3 million
33. IBS ELECTRONICS INC.	$37 million
34. NRC ELECTRONICS	$37 million
35. CRESTWOOD TECHNOLOGY GROUP	$33.7 million
36. ARCO INC.	$30 million
37. HAMMOND ELECTRONICS INC.	$29.6 million
38. AIR ELECTRO INC.	$26.4 million
39. MARCH ELECTRONICS	$23.9 million
40. DIVERSE ELECTRONICS	$21.9 million
41. PUI (Projections Unlimited)	$21 million
42. HOUSE OF BATTERIES	$20.4 million
43. KENSINGTON ELECTRONICS	$19.5 million
44. GOPHER ELECTRONICS	$19.3 million
45. Area 51 ESG	$18 million
46. CUMBERLAND ELECTRONICS STRATEGIC SUPPLY SOLUTIONS	$17.2 million
47. CT TRENDS	$17 million
48. 4 STAR ELECTRONICS	$13.8 million
49. COMPONENTS CENTER	$12.9 million
50. MARINE AIR SUPPLY	$12.8 million

[1] Sales figure reflects sales of computer/peripheral products.

[2] Sales figure reflects sales of computer/peripheral products.

[3] Future Electronics does not disclose yearly sales; rank is based on Global Purchasing estimates.

[4] Company-provided estimate for fiscal year 2015 ended March 31, 2015.

[5] Sales figure reflects worldwide sales for Premier Farnell, Newark, element14 for the fiscal year ended July 31, 2014.

Factory Automation

Continued from Page 78

moving too fast or by placing too much force on a package on the "push lanes," as Yager described it.

When pneumatics were used for this type of job, all the packages—regardless of weight and size—would be pushed together along a conveyor at the same rate of speed.

The electromechanical actuators have solved that damaged-package problem, he explained.

"With electromechanical actuators, I can take a look at that box with a camera and I can see that that box is a certain size," Yager said. "I can tell the actuator where to start pushing harder or where to start pushing less. And I can make sure that I don't pop a hole in it. You don't get as many problems with damage to material with electromechanical because you can control the velocity … [and] the torque and force at different points."

Don Weber, an electrical product manager at distributor J.H. Bennett's Novi, Mich., location, agrees, explaining that the psi (pounds per square inch) can be instantly adjusted with electromechanical actuators.

"They can regulate the pressure down to, let's say, 20 psi for a small package or maybe go up to 80 psi for a larger package, to kick it and give it the proper acceleration," Weber said. "We can do that with cylinders. Integrating the electronic pressure control right onto the cylinder is one of the things that we have been doing for years."

"One of the things we're doing is working with controls—electronic or electrical controls. We are integrating them a lot of times directly into units, functional units that actually do something," he said. "So we're putting some level of intelligence or control directly into a mechanical product, like a cylinder."

In the automotive assembly process, "resistance welding" is another example of where electromechanical innovation has been profitable for Bennett.

"Resistance welding is … when you see the pictures of cars being made and you see the sparks flying all over," Weber explained. "Those sparks are bad, actually, because that is metal being blown out of the weld. To control that, you control the pressure as well as the current, the time, and the energy put into the weld."

"You don't get as many problems with damage to material with electromechanical because you can control the velocity … [and] the torque and force at different points."
—Bob Yager, automation manager at Gulf Controls Company Inc.

Based about 30 miles from Detroit,

Continued on Page 84

EDS Features Celebrity Engineer Grant Imahara

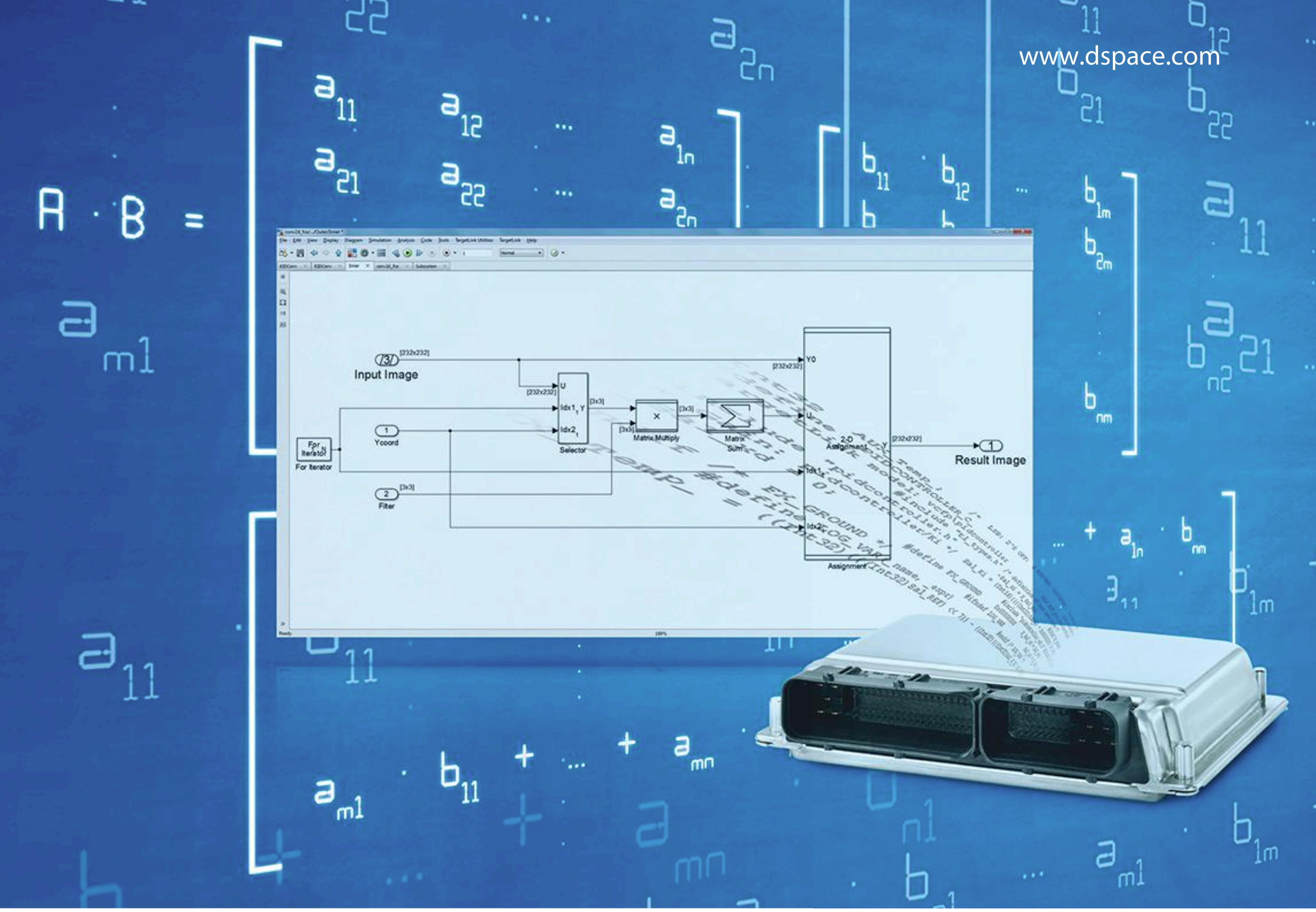
Members of the electronic components industry will connect at the Electronics Distribution Show, May 12-15 in Las Vegas..

MEMBERS OF THE Electronic Components Industry Association (ECIA) will meet this month for the annual Electronics Distribution Show (EDS) in Las Vegas. This is where distributors, manufacturers, and manufacturer representatives meet to discuss industry trends, issues, and challenges in a series of one-on-one business meetings, presentations, and networking events. EDS 2015 takes place at The Mirage Las Vegas, May 12-15.

The agenda includes a conference booth program, industry update and overview, awards presentation, and a kickoff reception featuring guest speaker and celebrity engineer Grant Imahara.

Imahara's talk is presented by Mouser and sponsored by Molex and EDS. Mouser and Imahara entered into a partnership late last year to promote industry

Continued on Page 84



TargetLink® – Production code generation for the toughest requirements

With dSPACE TargetLink, you can generate highly efficient ECU code straight from the graphical development environment MATLAB® / Simulink® / Stateflow®.

The production code generator provides extensive AUTOSAR support, ISO 26262 / IEC 61508 certification, integrated simulation and testing functionalities, and flexible configuration.

Whether your projects are AUTOSAR-compliant, conventional, or safety-relevant: TargetLink will cut your development time dramatically.

AUTOSAR

TÜV SÜD Functional Safety — Safety tested — Production monitored

Embedded Success dSPACE

Grant Imahara

Continued from Page 82

innovation through a series of events. The "Empowering Innovation Together" campaign features a series of design challenges, beginning with a robot challenge held earlier this year.

Imahara, best known for his work in the series "Mythbusters" and "Battlebots," is also the inventor of many robotic characters, including the Star Wars prequel-era R2-D2, The Late Show's Craig Ferguson sidekick Geoff Peterson, the talking robot, and the rhythmic arms on the modern-day Energizer Bunny.

EDS will also include its annual industry update meeting, with featured speaker Dr. Esmael Adibi, professor of economics at Chapmen University in Orange, Calif. Adibi is director of the university's A. Gary Anderson Center for Economic Research. His presentation will focus on an economic update and outlook, according to ECIA.

This year's conference also includes seminars sponsored by Spark—The EDS Professional Development Group. Spark seminars require separate registration.

For more information on EDS or to register, go to www.edsconnects.com. ■

Factory Automation

Continued from Page 82

J.H. Bennett is heavily involved in automotive assembly and related work.

"We do just about everything [in automotive]. We do everything from … tooling design [to] manufacturing where we do all the tooling and sensors for the end of an automation arm," Weber explained. "We build the whole tool that picks up the part and moves it around from assembly point to assembly point."

AEROSPACE TO ORANGE JUICE

Among the industries with which Gulf Controls works are manufacturers of flight simulators as well as packaging machines in which Florida's large orange juice makers do a great deal of work. Both industries require specialty suppliers who can save them time and improve overall operations.

"You get a lot of customers down here that do oranges and orange juice-type of applications," Yager said. "An orange-juice application would be lifting up huge 55-gallon drums of orange juice and dumping them into a vat. That can be done electromechanically or it can be done with hydraulics. With the packaging machines today, customers want more flexibility and they want faster speeds."

For flight simulators, Gulf Controls works with some Florida companies that in turn support the U.S. Air Force, commercial airlines, and even NASA.

Flight simulators have become realistic and sophisticated enough that young pilots can gain experience in scenarios such as losing an engine, flying into a wind shear, and flying with ice on the wings, Yager said.

"With a flight simulator, you have the cockpit of a fighter jet or commercial airline … sitting on a platform with electromechanical actuators," he explained. "And there is a 180-deg. theater in front of him showing the mountains of Afghanistan or the deserts of Saudi Arabia. All of a sudden, you might lose an engine and they have to adjust."

One side of the actuators will start rocking fast to simulate what happens with the loss of an engine or ice on the wings.

"What our company does is sell the electromechanical actuators and the motor-drive technology," Yager said. "And our customers will build the actual platform with the actuators and then integrate our control system into their theater and into their visualizations and their control systems for the pilot."

A particularly challenging project Yager and Gulf Controls was completing this past March was on technology that opens and closes a 70,000-pound hangar door.

Continued on Page 86

Factory Automation

Continued from Page 84

"We're working with a company that came out with a new technology for one-piece doors, airport doors," Yager said. "We're putting in a system that is electrohydraulics—an electrical control system that uses hydraulic cylinders, one on each side, to lift up a 160-foot door that weighs 70,000 pounds. We sync them together. It's pretty cool."

KEEPING UP WITH INNOVATION CURVE

Innovations in the overall technologies in which J.H. Bennett works are coming along faster than ever, Weber said.

"It's been growing for years and [manufacturers] are integrating products tighter and tighter. A lot of the manufacturers are doing that. One of our suppliers has added a lot of intelligence to something as simple as a vacuum generator," Weber noted. "It actually monitors the system for leaks. It has fault tolerance built into it. That is all on board in a molded control module … right on the vacuum system."

Cutting energy costs is something that more customers are looking to do these days.

People want to know the efficiency of their control system, Yager said. They want to know the efficiency of a particular machine. Energy savings often equals overall cost savings.

"Sometimes what they will do is shut off different areas of the plant or different areas of a machine to save energy during the day when [the price of] energy is going up," Yager said. "What they will do is actually manage their production to take advantage of the cost of energy on the machine. But they have to get that information—the amount of energy they're using versus the production that's being put out."

Robotics is also a factor for those taking advantage of new electromechanical solutions—especially when it comes to the tasks a robot can perform.

Various robotics have been used on auto assembly lines for quite some time, Weber said. While in some cases, this eliminates jobs, for others the challenge of learning the technology can pay off in better jobs. And safer ones as well, Weber added.

"Most of the factory floors have a significant amount of automation going on," he said. "It is whether or not you can handle the technology and work on it. That is where a lot of the jobs are now."

Weber referred to a metal press as an example of robotics making a task safer and more efficient.

"They don't want to have somebody loading a part into a press. There are safety concerns with that," he said. "It is a big, sharp sheet of metal and the press is a fairly dangerous object. If anything goes wrong, it can crush anything that is in there. So a lot of the press is automated. You feed it in one end, it goes through—it might be 150 or 200 feet long—and it comes out and it is a part, a recognizable fender or door."

Robotics are also being employed more often when potentially hazardous chemicals are being used, Yager noted.

"Maybe the chemical that is in that area isn't good for your lungs. Maybe it is in an area where there is high heat," Yager said. "We don't want human beings working in an area that might be 135 degrees all day. So we typically use robotics in areas that need a higher safety level and we need to get people out of that area and put them into other jobs in the facilities that are safe."

Both companies reported record years in 2014—with 2015 starting off strong as well.

Both companies have also been providing value-added engineering support for their customers when possible.

"The other thing we have done a lot on is engineering support for our customers," Yager explained. "We help them apply the technology of robotics, electromechanical actuators, electrohydraulic actuators … What we try to do is look at an application and apply the right technology and we will help them with movement to more automated systems, to new technologies, to wireless. We have a lot of experience in that."

At J.H. Bennett, Weber finds that customer demands require him to be a constant learner as new innovations come along.

"I learn something new every week, if not every day. That's one of the things I like to do, and in this job there is a lot of it," he said. "You can find different problems. A lot of times you can get called in on a problem and you will learn a whole bunch of stuff trying to solve it."

Top 50

Continued from Page 80

million. Most of the company's sales are to customers in Europe, with about 10% coming from outside the region. This also caused a shift, with N.F. Smith moving to the No. 12 spot, and DAC/Heilind moving to No. 13.

The entry of large independent distributor Fusion Worldwide at No. 14 also changes our rankings. The Massachusetts-based company had 2014 sales of $318 million, putting it just ahead of America II Electronics, which reported sales of $250 million in 2014. Also new to this year's list are Phoenics Electronics, at No. 29; Edge Electronics, at No. 31; NRC Electronics, at No. 34; Arco Inc., at No. 36; and Kensington Electronics, at No. 43.

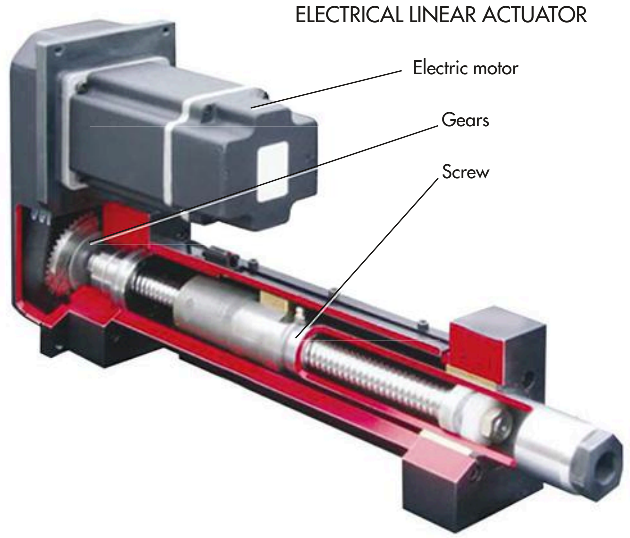
Missing from this year's list are two companies that were acquired during 2014: Electro-Sonic—which was purchased by No. 17 Master Electronics—and Astrex Electronics, which is now part of TTI. Other distributors that did not return this year either failed to submit a nomination form or fell below the $12.8 million cutoff figure.

Our goal is to provide a comprehensive list of the largest electronic components distributors serving customers around the world. We will begin compiling information for next year's report early in 2016 and we welcome your input. Send your questions or comments to sourceESBeditor@penton.com.

What's the Difference between Pneumatic, Hydraulic, and Electrical Actuators?

A LINEAR ACTUATOR moves a load, which can be an assembly, components, or a finished product, in a straight line. It converts energy into a motion or force and can be powered by pressurized fluid or air, as well as electricity.

Here is a breakdown of common linear actuators, their advantages and their disadvantages.



The electric motor is part of the actuator instead of being separate like a pneumatic or hydraulic system. While the electric linear actuator provides high precision, it does have large spacing requirements.

HOW THEY WORK

- Pneumatic linear actuators consist of a piston inside a hollow cylinder. Pressure from an external compressor or manual pump moves the piston inside the cylinder. As pressure increases, the cylinder moves along the axis of the piston, creating a linear force. The piston returns to its original position by either a spring spring-back force or fluid being supplied to the other side of the piston.
- Hydraulic linear actuators operate similarly to pneumatic actuators, but an incompressible liquid from a pump rather than pressurized air moves the cylinder.
- An electric linear actuator converts electrical energy into torque. An electric motor mechanically connected turns a lead screw. A threaded lead or ball nut with corresponding threads that match those of the screw is prevented from rotating with the screw. When the screw rotates, the nut gets driven along the threads. The direction the nut moves depends on which direction the screw rotates and also returns the actuator to its original position.

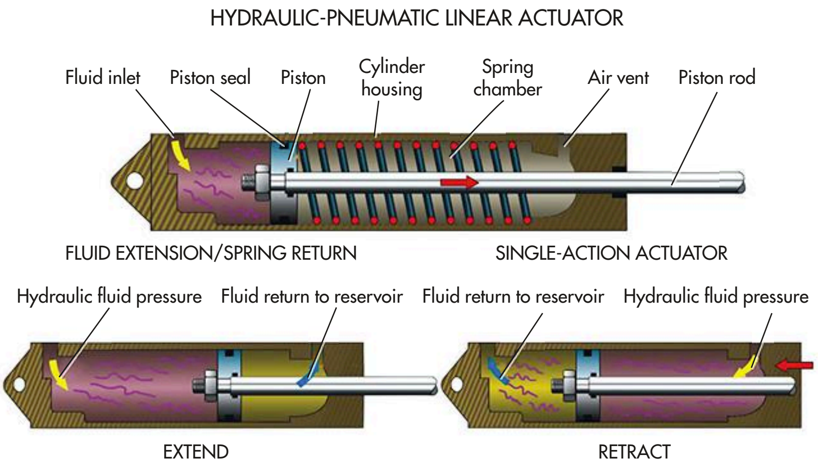
PNEUMATIC ACTUATORS

Advantages

- The benefits of pneumatic actuators come from their simplicity. Most pneumatic aluminum actuators have a maximum pressure rating of 150 psi with bore sizes ranging from ½ to 8 in., which translate into approximately 30 to 7,500 lb. of force. Steel actuators have a maximum pressure rating of 250 psi with bore sizes ranging from ½ to 14 in., and they generate forces ranging from 50 to 38,465 lbf.
- Pneumatic actuators generate precise linear motion by providing accuracy, for example, within 0.1 inches and repeatability within .001 inches.
- Pneumatic actuators' typical applications involve areas of extreme temperatures. A typical temperature range is -40°F to 250°F. In terms of safety and inspection, by using air, pneumatic actuators avoid using hazardous materials. They meet explosion protection and machine safety requirements because they create no magnetic interference due to their lack of motors.
- In recent years, pneumatics has seen many advances in miniaturization, materials, and integration with electronics and condition monitoring. The cost of pneumatic actuators is low compared to other actuators. According to Bimba Manufacturing, for example, the average pneumatic actuator costs from $50 to $150. Pneumatic actuators are also lightweight, require minimal maintenance, and have durable components that make pneumatics a cost-effective method of linear motion.

Disadvantages

- Pressure losses and air's compressibility make pneumatics less efficient than other linear-motion methods. Compressor and air delivery limitations mean that operations at lower pressures will



The image A shows a spring-return actuator. The maximum spring compression pushes back on the piston and the hydraulic fluid exits the cylinder and returns to its starting position. Image B is a double double-acting cylinder where fluid enters either side of the piston depending on the desired motion.

have lower forces and slower speeds. A compressor must run continually operating pressure even if nothing is moving.

- To be truly efficient, pneumatic actuators must be sized for a specific job. Hence, they cannot be used for other applications. Accurate control and efficiency requires proportional regulators and valves, but this raises the costs and complexity.
- Even though the air is easily available, it can be contaminated by oil or lubrication, leading to downtime and maintenance. Companies still have to pay for compressed air, making it a consumable, and the compressor and lines are another maintenance issue.

HYDRAULIC ACTUATORS

Advantages

- Hydraulic actuators are rugged and suited for high-force applications. They can produce forces 25 times greater than pneumatic cylinders of equal size. They also operate in pressures of up to 4,000 psi.
- Hydraulic motors have high horsepower-to-weight ratio by 1 to 2 hp/lb greater than a pneumatic motor.
- A hydraulic actuator can hold force and torque constant without the pump supplying more fluid or pressure due to the incompressibility of fluids
- Hydraulic actuators can have their pumps and motors located a considerable distance away with minimal loss of power.

Disadvantages

- Hydraulics will leak fluid. Like pneumatic actuators, loss of fluid leads to less efficiency. However, hydraulic fluid leaks lead to cleanliness problems and potential damage to surrounding components and areas.
- Hydraulic actuators require many companion parts, including a fluid reservoir, motors, pumps, release valves, and heat exchangers, along with noise-reduction equipment. This makes for linear motions systems that are large and difficult to accommodate.

ELECTRICAL ACTUATORS

Advantages

- Electrical actuators offer the highest precision-control positioning. An example of the range of accuracy is +/- 0.000315 inches in. and a repeatability of less than 0.0000394 inches. Their setups are scalable for any purpose or force requirement, and are quiet, smooth, and repeatable.
- Electric actuators can be networked and reprogrammed quickly. They offer immediate

> “Hydraulic actuators can produce forces 25 times greater than pneumatic cylinders of equal size.”

feedback for diagnostics and maintenance.
- They provide complete control of motion profiles and can include encoders to control velocity, position, torque, and applied force.
- In terms of noise, they are quieter than pneumatic and hydraulic actuators
- There are no fluid leaks and environmental hazards are eliminated.

Disadvantages
- The initial unit cost of an electrical actuator is higher than those for that of pneumatic and hydraulic actuators. According to the example from Bimba Manufacturing, an electrical actuator can range from $150 to greater than $2,000, depending on its design and electronics.
- Electrical actuators are not suited for all environments, unlike pneumatic actuators, which are safe in hazardous and flammable areas
- A continuously running motor will overheat, increasing wear and tear on the reduction gear. The motor can also be large and create installation problems.
- The motor chosen locks in the actuator’s force, thrust, and speed limits to a fixed setting. If a different set of values for force, thrust, and speed are desired, the motor must be changed. md

What's the Difference between Batteries and Capacitors?

BATTERIES AND CAPACITORS seem similar as they both store and release electrical energy. However, there are crucial differences between them that impact their potential applications due to how they function differently.

SUPERCAPACITORS

A capacitor consists of two or more conductive plates separated by a dielectric. When an electric current enters the capacitor, the dielectric stops the flow and a charge builds up and is stored in an electric field between the plates. Each capacitor is designed to have a particular capacitance (energy storage). When

Three packs of supercapacitors (in the blue package), consisting of six D-size cells. Each 18 cells total were able to provide and store the same amount of electrical energy as the smaller pack of six AA-size TLI 1550 Li-ion rechargeable batteries.

PERFORMANCE COMPARISON

Function
Charge time
Cycle life
Cell voltage
Specific energy (Wh/kg)
Specific power (W/kg)
Cost per Wh
Service life (in vehicle)
Charge temperature
Discharge temperature

Source: Battery University

a capacitor is connected to an external circuit, a current will rapidly discharge.

BATTERIES

Different battery types are distinguished by their chemical makeup. The chemical unit, called the cell, contains three main parts: a positive terminal called the cathode, negative terminal called the anode, and the electrolyte. The battery charges and discharges through a chemical reaction that generates a voltage. The battery is able to produce a constant stream of electricity that can be turned on and off. In rechargeable batteries, the chemical energy that is converted into electricity can be reversed using an outside electrical energy to restore the charge.

DIFFERENCES

While batteries and capacitors have similarities, there are several key differences. The potential energy in a capacitor is stored in an electric field, where a battery stores its potential energy in a chemical form. The technology for chemical storage currently yields greater energy densities (capable of storing more energy per weight) than capacitors. However, when a battery is discharging it can be slower than a capacitor's ability to discharge because there is a latency associated with the chemical reaction to transfer the chemical energy into electrical energy. A capacitor is storing the electrical energy directly on the plates so discharging rate for capacitors are directly related to the conduction capabilities of the capacitors plates. A capacitor is also able to discharge and charge

BETWEEN SUPERCAPACITOR AND LI-ION

Supercapacitor	Lithium-ion (general)
1–10 seconds	10–60 minutes
1 million or 30,000h	500 and higher
2.3 to 2.75V	3.6 to 3.7V
5 (typical)	100–200
Up to 10,000	1,000 to 3,000
$20 (typical)	$0.50-$1.00 (large system)
10 to 15 years	5 to 10 years
–40 to 65°C (–40 to 149°F)	0 to 45°C (32°to 113°F)
–40 to 65°C (–40 to 149°F)	–20 to 60°C (–4 to 140°F)

faster than a battery because of this energy storage method. But unlike a battery that can turn its electrical current on and off, once a capacitor is connected to an outside circuit it will discharge as fast as it can until all the charge is drained.

BATTERIES	
Pros	**Cons**
Power Density	Limited Cycle Life
Storage Capability	Voltage And Current Limitations
Better Leakage Current Than Capacitors	Long Charging Times
Constant Voltage That Can Be Turned Off And On	More Temperature Sensitive Than Capacitors
CAPACITORS	
Pros	**Cons**
Long Cycle Life	Low Specific Energy
High Load Currents	Linear Discharge Voltage
Short Charging Times	High Self-Discharge
Excellent Temperature Performance	High Cost Per Watt

This table compares the pros and cons of batteries and capacitors

> "The potential energy in a capacitor is stored in an electric field, where a battery stores its potential energy in a chemical form. The technology for chemical storage currently yields greater energy densities than capacitors."

While other differences exist, batteries and capacitors do have some overlapping applications. However, in general batteries provide higher energy density for storage, while capacitors have more rapid charge and discharge capabilities (greater power density). The demand for fast portable power has researchers trying to increase charging and discharging times in batteries, while increasing storage capacity in capacitors. While research continues to improve batteries and capacitors, there are still have distinct characteristics that make each applicable to individual uses. md

What's the Difference between Resistance-Welded Fasteners and Arc-Welded Studs?

WELDING IS OFTEN used to permanently fasten two pieces of metal together, often by robotic welders. Screws and nuts are the most common welded fasteners, but pins and unthreaded studs are often used as locating or bearing surfaces rather than fasteners. There are two general groups of welded fasteners: resistance welded ones and arc-welded studs. So what's the difference?

RESISTANCE-WELDED FASTENERS

Resistance-welded fasteners are internally or externally threaded parts meant to be permanently fused in place by standard welding equipment.

The two methods used in resistance welding are:

Projection welding: In this method, heat from the welder gets

focused on a fastener's embossed or coined projections. This fuses the projections with the surface of the metal base and forms a weld. A press-type welder with electronic controls is recommended for this task because it provides positive electrode alignment and equalized welding pressures.

Spot welding: In this welding process, current is sent

through the entire area under the electrode to fuse the fastener and metal base together. This is often done with a rocker-arm type of spot welder because it can handle a variety of different types of welds and fastener designs. The equipment needed for spot welding is less expensive than that needed for projection welding. On the other hand, projection welding is more versatile and gives engineers more latitude in their designs.

For good results, both the part and material must be suitable for resistance welding. Low-carbon 1010 steel is the most commonly used material for spot-welded fasteners. Parts also must be portable because they must be transported to the welding machine. Portable welders are not recommended for use on these types of fasteners. To justify the costs of welding and make it economically feasible, production volumes should number at least 1,000.

The most common use of resistance-welded fasteners is with sheet metal parts measuring 0.03 to 0.125-in thick. But any size fastener can be welded to material of any thickness if the materials are compatible, the welding properly controlled, and the fastener well designed.

ARC-WELDED STUDS

In stud welding, the heat from an electric arc created between the fastener and the part to which it is being joined melts metal on both components. The two parts are then brought together under pressure. When the parts cool, the two parts are fused and the joint is complete.

Both the fastener and material must be weldable and one end of the fastener must be designed to be heated and fused to another part. Stud welds are leak-proof, pressure-tight, and can be made using automatic and semiautomatic equipment. Automatic welders can turn out 60 welds per minute.

There are two general methods of stud welding: electric arc and capacitor discharge.

Electric-arc stud welding: This is the most common stud-welding method and it is largely semiautomatic. In the process, dc current from a motor-generator or transformer-rectifier passes in an arc from the stud (electrode) to the metal plate and creates heat. The

weld cycle is a function of stud diameter and varies from 0.1 to 1.5 seconds.

When the weld is complete, the entire cross-sectional area of the stud is fused to the base metal, making a strong bond. For the best results, the base metal or plate should be heavy enough to support the full strength of the welded fastener. However, lighter-gauge metal materials are also often arc-welded. To avoid burn-through, one rule of thumb says the plate should be at least 20% as thick as the diameter of weld at its base. For a weld that is as strong as the faster will allow, the plate should be at least one-third as thick as the diameter of the weld at its base.

The most commonly used fasteners for electric-arc stud welding are made of low-carbon steel that has a minimum tensile strength of 60,000 psi and a minimum yield strength of 50,000 psi. High-grade fasteners comparable in strength to SAE grade 5 bolts are also used.

This form of arc welding can be used on round and angled surfaces, as well as flat ones, because it relies on the stud's ferrule to provide the molted metal that harden into create the weld.

Capacitor-discharge stud welding: In this process, the arc generated by the rapid discharge of electricity from a capacitor generates the metal-melting heat. Pressure applied during or immediately after the discharge completes the joint. Just as in arc welding, the heat is created by current passing in an arc from the stud to the plate.

One advantage of the capacitor-based welding is that it can weld studs to thin materials without thermally distorting or discoloring them and without burn-through. The weld is not that deep into the plate, so dissimilar metals can be welded without metallurgical problems. Plates can be as thin as 0.016 in for steel and 0.04 in. for aluminum.

Fasteners used in capacitor-discharge welding are generally made from annealed C-1008 or C-1010 steels. Tensile strengths range from 40,000 to 50,000 psi. Nonferrous fasteners are made from magnesium-aluminum and silicon aluminum, and austenitic steel. To get the most from this form of welding, the metal plate should be flat or nearly flat. md

Mounting Kits Facilitate Sensing Capabilities in Jaw Travel

MOUNTING KITS for Series JC1STP teachable two-position switches are now available as accessories for Series 8400 and 109/191 grippers. The kits include a switch plate that contains slots, allowing one or two switches to mount to the bottom of the grippers. Mounting two switches allows for sensing of four jaw positions throughout jaw travel. According to developer PHD, the kits lower cost for jaw-position sensing by up to 50%. They can be retrofitted and are easy to install and set up. The switches and mounting plates are ordered separately.

PHD INC., P.O. Box 9070 Fort Wayne, IN 46899; (260) 479-2265

Holding on Tightly with Coil-Spring Battery Holders

THE COIL-SPRING contact SMT and THM battery holders ensure proper polarity and tension for cylindrical

batteries. Housed in heat-resistant nylon and featuring low-contact-resistance, gold-plated, stainless-steel contacts, the devices handle traditional or lead-free soldering, as well as reflow processing. Through-hole-mount versions are equipped with nickel-plated stainless-steel contacts. Retaining covers are available for additional battery security. Holder types accommodate AA, AAA, 1/2AA, and CR123A cylindrical batteries. They're also compliant with ISO-9001:2008 and RoHS.

KEYSTONE ELECTRONICS CORP., 31-07 20th Rd, Astoria, NY 11105, (800) 221-5510, www.keyelco.com kec@keyelco.com

Reverse-Displacement Motors Target Large Machinery

OPEN-CIRCUIT PISTON motors, when used with Danfoss reverse-displacement motors (RDMs), feature reverse-circuit functionality to eliminate external valves. Specifically,

their 12- or 24-V integrated proportional shifting valves allow for smooth reversing using the system's pressure, thus eliminating external valves and external pressure supplies. Reverse functionality of the RDM enables the fan to purge trapped dirt and debris, restoring cooling efficiency. The piston motors are compatible with larger machinery that have displacements as high as 38 and 45 cc. Along with 10% savings in power and a 15% average reduction in total system costs, they help diminish system complexity. A new speed-sensor option provides precision control for system efficiency.

DANFOSS POWER SOLUTIONS, 2800 East 13th St, Ames, Iowa 50010; (515) 239-6208, www.powersolutions.danfoss.com

Monofilament Braid Sleeves Protect Wiring and Cables

ATKINS AND Pearce's Armour Guard line offers 11 expandable monofilament sleeves for protecting wires, cables, and hoses in a variety of environments. Heavy-duty braids target rugged applications for abrasion protection. Flame-retardant braids are used in industrial and high-tech applications to quickly self-extinguish and minimize fire damage and spreading. In addition, Halar braids for HVAC applications prevent toxic gases from spreading in a system and are resistant to high temperatures. The sleeves come in sizes ranging from 3/16 to 5 in.

ATKINS AND PEARCE, 1 Braid Way, Covington, KY 41017; (800) 837-7477

Precision Ring Drive Indexers Start/Stop at All Positions

ACCORDING TO Nexen Group, its Precision Ring Drive Indexers (PRDs) direct drive motors twice as fast as other indexing options. By combining precision-grade bearing and gearheads with Roller Pinion technology, the PRDs can start and stop at any incremental position. A new motion profile can be installed simply by loading a new servo drive into the system. The large hollow center facilitates cable mounting through the center of the rotating plate. Rated for loads up to 1575 kN, the indexer is supported by high-capacity cross-roller bearings. It's capable of speeds up to 94 rpm, and can handle peak torque inputs at all times.

NEXEN GROUP INC., 560 Oak Grove Parkway, Vadnais Heights, MN 55127; (800) 843-7445, www.nexengroup.com

Compact Power Supplies Have Configurable Outputs

TDK LAMBDA'S CUT75 low-profile, triple-output power supplies, measuring 3 by 5 by 1.06 in., will fit numerous industrial, broadcast, and test-and-measurement applications. Input voltage from 85 to 265 V ac is required for the two standard models; both produce 75-W output power. The CUT75-522 features a 5-V, ±12-V output voltage, while and the CUT75-5FF has a 5-V, ±15-V output. Units can be configured as dual-output power supplies (5 V, ±24 V; or 5 V, ±30 V) by connecting outputs 2 and 3 in series.

There's no minimum load operation. The 5-V output is user-adjustable from 5 to 5.25 V. The series features an operating temperature range from –20 to 70°C ambient (with appropriate de-rating above 60°C). All CUT75 supplies carry a three-year warranty.

TDK LAMBDA, 401 Mile of Cars Way, Suite 325, National City, CA 91950; 800-LAMBDA-4

Photo Etching Produces Thin, Burr-Free Parts

THANKS TO photo-etching technology, Tech-Etch is able to create burr-free, thin metal parts—even intricate and complex shapes. Parts are as thin as 0.0005 in., and consist of stainless-steel alloys, Inconel, Hastelloy, titanium, niobium, nitinol, and magnesium. Parts are suitable for medical, industrial, and aerospace applications. Other manufacturing materials are MP35N used in implanted devices, Elgiloy used in replacement heart valves, and 716 and 420 alloys targeted for surgical blades. Photo etching eliminates expensive tooling, and helps speed turnaround times. Forming, heat treating, plating, laminating, and assembly are available in-house.

The *Precision Engineered Parts Capabilities Brochure* is available on the Tech-Etch website.

TECH-ETCH INC., 45 Aldrin Rd., Plymouth, MA 02360; (508) 747-0300, www.tech-etch.com

Plug Connectors' Manual Interrupt Prevents Shock

THIS EM30MSD Series of plug connectors provides manual service disconnect in order to protect operators from shock in high-voltage environments. Supporting currents as high as 200 amps, its bayonet lock switch can be quickly and safely turned to the "off" position in order to provide shock resistance. This interrupts current flow to ensure electrical safety during maintenance or cleaning. The multiple contact design decreases contact resistance to provide high current capacity. It is rated to 50 mating cycles and has a waterproof housing. Standard crimp terminals can be used with the plug connector.

HIROSE ELECTRIC INC., 2688 Westhills Court, Simi Valley, CA 93065; (805) 522-7958, www.hirose.com/us

Brushless DC Motors Offer Length, Winding Options

THE EC044A Series of slotted brushless dc motors features three motor lengths and 24 winding variations, as well as custom lengths and windings. With a diameter of 1.7 in., the motor body is compact and capable of no-load speeds as high as 15,000 rpm. The small motor is rated for a continuous output torque of 15 oz-in. With available Ametek gearbox technology, motors can produce output torques as high as 4400 oz-in.

The motor is made of aluminum with a 400 Series stainless-steel shaft. The four-pole rotor integrates high-energy neodymium magnets, while the internal circuit board takes advantage of hall-sensor feedback with spacing at 120 electrical degrees. The EC044A motors also come with pre-loaded and shielded ball bearings, as well as features to produce low cogging torque, low vibration, and quiet operation. Optional versions feature a drive, higher IP class, and other variations.

PITTMAN MOTORS, 343 Godshall Drive, Harleysville, PA 19438; (267) 933-2105, www.pittman-motors.com

Detectable Plastic Proves Safer for Food-Processing Equipment

A FAMILY of plastics, detectable in food via x-ray machines and metal detectors, becomes an optimal choice for kettle scraper blades, impellor parts, and pump valves employed in food processing. Extensive testing on HYDEX 4101 UD blue shows 100% detectability in pieces that are as small as 4 mm. In pieces as small as 3 mm, the product was detectable 99.5% of the time.

Using the TECAFORM UD blue, TECAFORM FG blue, and HYDEX 4101 UD blue detectable product lines will minimize the risk of shipping food that contains plastic debris, says Ensinger. The company suggests customers do their own testing, though.

ENSINGER INC., 365 Meadowlands Boulevard, Washington, PA 15301; 800-243-3221

AC Motor Plus Controller Manages Vertical-Load Speeds

THE DSC Series motor-and-controller package provides speed control in systems with up to 20 axes and even supports vertical speed control with a deceleration-control electromagnetic brake. According to Oriental Motor, the two components are easy to use and provide closed-loop ac speed control, requiring only single-phase input of 110/115 or 220/230 V ac. The long-life ac gear motors are capable of outputs from 6 to 90 W, producing output torques as high as 350 lb-in. Programmable functions are displayed on the front face of the controller, including an LED readout for monitoring.

ORIENTAL MOTOR USA CORP., 2320 Touhy Ave., Elk Grove Village, IL 60007; (847) 871-5900 www.orientalmotor.com, sales@orientalmotor.com

Terminal Blocks Feature Pushbutton Wire Release

WAGO'S 2061 surface-mount terminal blocks facilitate insertion and removal of stranded and solid conductive wires with pushbutton release. The models allow connection of stranded wires up to 1.5 mm^2 (AWG 16), and have a direct plug-in for solid conductors. The 2061 substantially reduces on-board LED shadowing, standing a mere 5.6

mm high and having a light color profile. They come in tape-and-reel packaging for automated wiring systems and maintain 6-mm pin spacing. The 2061 PCB terminal blocks come in 1-, 2- and 3-pole versions and can be arranged side-by-side without any pole loss.

WAGO; N120 W19129 Freistadt Rd., Germantown, WI 53022; 1-800-DIN-RAIL, info.us@wago.com

Adjustable Clamps Provide up to 8-kN Thrust Force

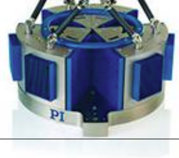
THE GN 927.5 Stainless Steel Clamping Levers have an eccentric cam to be used for virtually torque-free clamping via downward vertical and cam-actuated motion. Type-A clamps have an adjustable contact plate with a setting nut for variable clamping force, while Type-B clamps have a fixed contact plate. Levers are made out of Series 303 stainless steel, and contact plates consist of black technopolymer that's reinforced with glass-fiber. Thrust forces up to 8 kN are possible. Versions with threaded studs are available.

JW WINCO, INC., 9406 N. 107th St., Milwaukee, WI 53224; (414) 354-0200, www.jwwinco.com

Keep Electronic Enclosures Cool with Minimal Compressed Air Levels

DIGITAL ELECTRONIC Temperature Control (ETC) keeps electrical enclosures cool while optimizing compressed air levels for consistent and economical temperature control. ETCs are compatible with large or high-heat load enclosures with cooling capacities as high as 5600 Btu/hr. They are suitable for NEMA 4, NEMA 4X, and NEMA 12 environments. A digital LED readout displays the electrical enclosure temperature and allows the user to adjust temperature settings. The Cabinet Cooler System is activated when the temperature exceeds the maximum temperature defined by the user. Models are available for 120- or 240-V ac power sources.

EXAIR CORP., 11510 Goldcoast Dr., Cincinnati, OH 45249, (800) 903-9247 www.exair.com



Hexapod Features Six Degrees of Freedom, Vibrational Accuracy

THE H-860KMAG six-axis Hexapod can perform highly dynamic motions and vibrational stimulations. The hexapod replaces conventional roll-bearing elements with non-contact PIMag voice-coil linear motors, guided with virtually frictionless flexures. This reduces motor noise and wear, and the need for lubricant.

The hexapod demonstrates 4 g acceleration at small-signal operating frequencies as high as 100 Hz, and can reach velocities of 250 mm/sec. In compliance with standard CIPA testing, the hexapod can emulate a camera shake when taking photographs. It's suitable for motion simulation, image-stabilization testing equipment, vibration simulation, precision positioning, and alignment of opto-mechanical components. The open-software architecture and digital-vector motion controller allow users to change the pivot point (or center of rotation), pre-defined trajectories, and sinusoidal curves, all while freely defining paths with high accuracy.

PHYSIK INSTRUMENTE (PI), 16 Albert St., Auburn, MA 01501, (508) 832-3456, www.pi-usa.us, info@pi-usa.us

Laser Galvanometer Improves Reliability in Laser-Etching Apps

THE NEW laser galvanometer interface for Delta Tau's Power PMAC motion controller improves controls for applications such as laser marking, PCB processing, micromachining, and medical device manufacturing.

With its single-controller architecture, programmed for both the scanner and motion axes, the galvo positions the scanning head relative to the work piece based on the industry's XY2-100 communication standards. The unified controller reduces stitching errors, or errors at the laser-scanning boundary, which can occur in systems that use two controllers for the motion axes and scanner. The interface also utilizes a single program to allow for direct synchronization with general motion axes and vary laser power through PWM outputs. In addition, the single program speeds up the process by simultaneously positioning the galvo mirrors in the laser scanner and the x-y position of the work piece.

DELTA TAU INC., 21314 Lassen St. Chatsworth, CA 91311; 818-998-2095

Motion Controller Chips Eye High-Speed Linear Motors

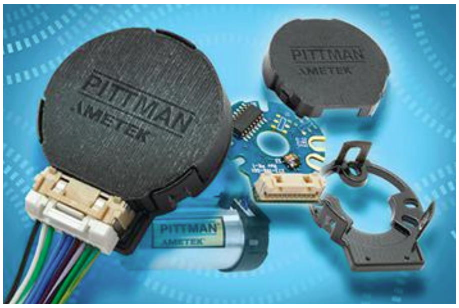
THE LATEST Nippon Pulse PCL61x4 series of motion-controller chips includes single-axis PCL6114 and four-axis PCL6144 chips. Both models are high-performance servo/stepper controller chips with SPI serial busses for four-wire connections, and work well with high-speed, high-resolution linear motors in industrial settings. There are 27 event factors available with programmable software limits to initiate interrupt-signal outputs. Built-in

pre-registers allow continuous operation, linear interpolation, and nine major operating modes. The chips have input terminals for manual pulsers, jog switches, and limit/homing switches. They are compatible with Nippon Pulse's Linear Shaft Motors in high-precision applications such as semiconductor processing or microscopic image scanning.

NIPPON PULSE AMERICA INC., 4 Corporate Drive, Radford, VA 24141; 540-633-1677, www.nipponpulse.com

Encoder Duo Comes in 64 Possible Configurations

PITTMAN'S SMALL-DIAMETER, low-profile E30C and E30D optical incremental encoders are available in 64



different configurations with two or three channels. Connections feature locking radial or axial connectors. The 30C offers resolutions between 200 and 500 at an operating frequency of 40 kHz. The 30D's resolution ranges between 500 and 2048, at an operating frequency of 55, 110, or 220 kHz. Both encoders output two-channel, TTL-compatible quadrature signals. The 30D also offers an optional third-channel index output and complementary outputs.

PITTMAN, 343 Godshall Dr., Harleysville, PA 19438; (330) 673-3452

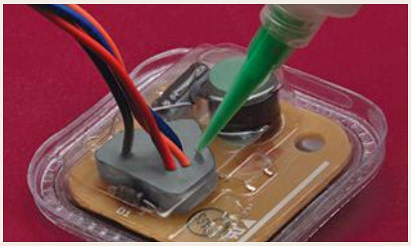
Compact Double-Stack Linear Actuators Housed in Small Package

THE 21000 Series of size 8 double-stack linear actuators have patented technology for high-performance, high-endurance motion. With a compact size of 0.8 in.^{2}, the actuators deliver thrust as high as 7.7 kg and have resolutions ranging from 0.0025 to 0.04 mm per step. Microstepping is possible with these models for finer resolution. Thermoplastics are incorporated into the rotor drive nut, and the acme lead screw is made of stainless steel. Models are available in capacitive, non-capacitive, and external versions.

HAYDON KERK, 1500 Meriden Road, Waterbury, CT 06705; (203) 756-7441, www.haydonkerk.com

Silicone System Boasts Electrical Insulation, Thermal Conductivity

MASTERSIL 156 is a two-part, addition-cured silicone system useful for high-performance potting, encapsulation, and sealing. With moderate viscosity and a curing schedule of one to two hours at 250°F, MasterSil 156 passes



UL 94V-0 testing for flame retardancy at temperatures up to 105°C, and features high-temperature resistance, flexibility, high thermal conductivity, and electrical insulation. MasterSil 156 does not require air exposure for complete cross-linking, and does not outgas while curing. With a 1:1 mix ratio by weight, it is 100% solids and contains no solvents. It bonds well to metals, composites, glass, ceramics, and many rubbers and plastics. It is resistant to water, humidity, and oils.

MASTER BOND INC., 154 Hobart St., Hackensack, NJ 07601, (201) 343-8983, www.masterbond.com

machine design
BY ENGINEERS FOR ENGINEERS

MAY 2015
machinedesign.com

LITERATURE Express

ATN CONVERTIBLE PROFILE TIMING BELT DESIGN

BRECOflex, CO., L.L.C., the world leader in the polyurethane timing belt industry, has developed a patented timing belt system that allows the customer to rapidly and easily attach profiles or product nests of any material directly to the belt. Profiles may be installed, replaced, or exchanged while the belt is installed. Additionally ATN technology opens up the possibility for a field connection option using simple hand tools.

BRECOflex also offers a full range of accessories including pulleys, clamps, tensioners and slider beds.

For your *FREE* copy, samples and technical support, visit our website at *www.brecoflex.com* or call *732-460-9500*.

2015 NEW PRODUCTS CATALOG

Hercules is pleased to announce the release of the 2015 New Products Catalog. This new catalog features new and expanded product lines to meet your repair needs. New inch product lines include the BHT high strength Rod, Piston, Symmetrical and Buffer Seals. New metric offerings include MYR-HT Buffer Seals, MPSQ5 Piston Seal Assemblies, MSWSHN Wiper Rings, and MHS8 O-Rings. Kits have been expanded to include new seal kits for Case, Caterpillar®, Hitachi, JCB, Kubota, Volvo and many more.

To order your free copy of the Hercules 2015 New Products Catalog, visit the Company Literature section of the Hercules website at ***www.HerculesUS.com*** or call ***888-525-0094***.

ADVANCED CERAMIC SOLUTIONS

Astro Met's unique advanced ceramics provide cost effective solutions to material performance problems in a wide range of demanding applications. "Amalox 68" a 99.8% alumina ceramic and "Amzirox 86" an yttria stabilized zirconia provide superior wear resistance, corrosion resistance, high temperature stability, low thermal expansion, high stiffness to weight ratio, biocompatibility and high dielectric strength.

Astro Met, Inc.
Cincinnati, OH
(513) 772-1242
Fax: (513) 772-9080
Email: fgorman@astromet.com
Web: www.astromet.com

ALTECH INDUSTRIAL ENCLOSURES

Altech offers a broad selection of non-metallic and aluminum Industrial Enclosures to meet your diverse design requirements. Sizes range from 1.97 x 2.05 x 1.38 to 35.43 x 11.81 x 5.59 inches.Materials include polycarbonate, polystyrene, polypropylene, ABS or aluminum. Polycarbonate and aluminum series have been recently expanded. Protection up to IP67 (NEMA 4, 4X). Smooth sidewalls or sidewalls with knockouts. Enclosures can be mounted directly onto a panel, frame or other mounting surfaces. EMI / RFI Coating is available. Competitive cover printing is available Hinge Kits. Customization available.

Visit ***www.AltechCorp.com*** or call ***908-806-9400***.

ALTECH DIN RAIL POWER SUPPLIES

Altech DIN RAIL mountable power supplies have Universal AC input. They are suitable for industrial and automation applications.

- UL508 Listed or UL Recognized
- Single and Three phases up to 960W
- Outputs of 5V, 12V, 15V, 24V and 48V
- Class 2 devices are available
- Installed on DIN rail TS35/ 7.5 or 15
- Protections of Short circuit / Overload /Overvoltage / Over temperature
- Cooling by free air convection
- All-In-One DC-UPS, battery based
- Ultra Capacitor DC-UPS, no battery required
- Worldwide approvals
- 3 year warranty

Visit ***www.AltechCorp.com*** or call ***908-806-9400***.

ALTECH SAFETY PRODUCTS

Altech now offers the BERNSTEIN line which is renowned for safety products, sensors and foot switches. The comprehensive line of products fully meets relevant safety requirements across a wide range of specific applications. Products include:

- FootSwitches
- Enclosures (Stainless, Aluminum and Polyester)
- ATEX Enclosures (Polyester) • Safety Interlock Switches
- Solenoid Interlock Switches • Cable Rope Pull Switches
- Hinged Door Switches • Standard & Safety Foot Switches
- RFID Non Contact Safety Switches
- Safety Relay & Control Modules • Standard Limit Switches
- Safety Limit Switches • AS-i Safe Intelligent Sensors
- Inductive Switches • Capacitive Switches
- Cylinder Slot Sensors • Magnetic Switches
- Optical Switches • Float Switches
- Ultra Capacitor DC-UPS, no battery required
- Worldwide approvals • 3 year warranty

Visit ***www.AltechCorp.com*** or call ***908-806-9400***.

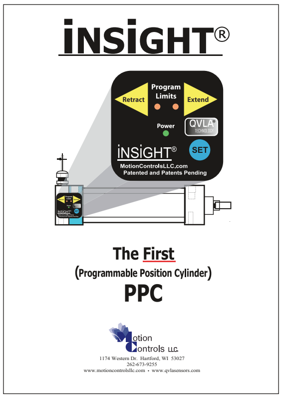
ALTECH TEST AND MEASUREMENT

Products include:

- Plunger Style Test Clips for measuring difficult to access testing points.
- Test Probes, Slim and compact body for easy access.
- Oscilloscope Test Probes with 10:1 probe ratio.
- Alligator Clips with various clamping ranges.
- Measuring Leads, a wide variety of colors, length and connections.
- Test Plugs with various connection types.
- Test Jacks, screw-in and press-in versions.
- Altech offers a variety of Test & Measurement Sets consisting of suitable components for certain System Types and specific applications.

Visit ***www.AltechCorp.com*** or call ***908-806-9400***.

PROGRAMMABLE AIR CYLINDER



Brochure highlights InSight series of programmable position cylinders (PPC), which are repairable tie-rod air cylinders with embedded electronics that provide a pair of user programmable stop points. The cylinder design features both NFPA and non-NFPA configurations. The brochure highlights key features and specifications (1500 Hz response, 5 million cycle life, repeatability of 0.030 in., and more); engineered drawings highlighting cylinder, cap end, rod end, and mounting styles and dimensions; and ordering information.

Motion Controls LLC
1174 Western Drive Hartford WI 53027
Voice: **(262) 673-9255**
Web: **www.motioncontrolsllc.com**

ELECTRIC CYLINDERS

RACO Electric Linear Cylinders with ballscrews or acme screws are an environmentally safe and low maintenance replacement for hydraulic or pneumatic cylinders. Thrusts to 200,000 lbs., speeds to 30"/second, and strokes to 20 ft. Modular system allows custom built units using the special high torque RACO actuator motor or servo and stepper motors. Cylinders are built for heavy duty industrial applications. Other types of cylinders are available for high speed, high positioning accuracy applications.

RACO International L.P.
Bethel Park, PA
(888) 289-7226, (412) 835-5744
Fax: (412) 835-0338
Email: raco@racointernational.com
Web: www.racointernational.com

TURBO® MINIATURE PIEZOELECTRIC ALARMS

Tiny (approx.1"x1") piezoelectric alarms provide LOUD output with a super-sleek design. Available in variety of voltages and output up to 103dB! Rugged, tamper-proof, lo-profile panel mount design is IP68 and NEMA 4X. Optional manual volume control offers increased attenuation. ISO 9001:2000 registered company – all products made in the USA.

Floyd Bell Inc
(614) 294-4000
Fax: (614) 291-0823
Email: sales@floydbell.com
Web: www.floydbell.com

At EngineeringTV.com users can browse video libraries using technology-based navigation to focus on specific technology topics. They can also browse by company brand, trade show, or by publication-specific video "playlists."

From tutorials to trade-show coverage, Engineering TV is *the* video site for design-engineering professionals.

engineering tv

Ad index

ADVANCED MACHINE & ENGRG CO. . . . 14
AEROTECH INC. 45
AIRPOT CORP/AIRPEL. 68, 69
ALL MOTION 88
ALLIED ELECTRONICS 79
ALTECH CORP. . . . . IFC
AMACOIL INC.. 106
APPLIED MOTION PRODUCTS 47
AUTOMATIONDIRECT.COM 3
B&R INDUSTRIAL AUTOMATION 40
BALDOR ELECTRIC CO. . . . . IBC
BALLUFF INC. 30
BANNER ENGINEERING CORP.. 51
BIMBA MFG CO. . . . . BC
BODINE ELECTRIC CO. 73
CARLYLE JOHNSON MACHINE CO. . . . 42
CENTRICITY CORPORATION 72
CLIPPARD INSTRUMENT LAB INC. . . . 94
CORRY RUBBER 91
COUNTERBALANCE CORP. 64
CRAFTECH INDUSTRIES, INC. 13
DELTA COMPUTER SYSTEMS 70
DELTA TAU DATA SYSTEMS 104
DIEQUA CORPORATION. 71
DORNER MFG CORP. 92
DSPACE 83
DYNATECT MANUFACTURING INC. . . . 103
DYNOMOTION 101
EBM-PAPST, INC. 9
EXLAR ACTUATION SYSTEMS 98
FABCO AIR, INC. 95
FLOYD BELL INCORPORATED 86
FRABA 84
GRAPHITE METALLIZING CORP. 46
GRIPNAIL 50
HBM INCORPORATED. 18
HELIX LINEAR 26, 28, 29
HERCULES SEALING PRODUCTS 77
HIWIN CORPORATION. 41
IGUS INC. 6
IKO INTERNATIONAL INC. 105
INTECH POWERCORE CORPORATION . . . 24
INTERROLL AUTOMATION, LLC 102
KAMAN INDUSTRIAL TECHNOLOGIES 5
KEPNER PRODUCTS CO. 46
KETTERER INC. 22
LIN ENGINEERING 85
LUBRIPLATE LUBRICANTS CO. 34
MAXON MOTOR USA 107
METAL POWDER IND FEDERATION . . . 58, 59
MICROMO ELECTRONICS. 75
MINALEX CORP. 72
MK NORTH AMERICA. 93
MOOG COMPONENTS GROUP 11
MOTION CONTROLS, LLC. 86
MTI INSTRUMENTS 91
MTS SYSTEMS CORP. 36-37
NANNI INGRANAGGI 62
NASON CO. 63
NATIONAL INSTRUMENTS 15
NEUGART USA. 99
NEWARK 23
NEWPORT CORPORATION 97
NIPPON PULSE AMERICA INC. 90
NOVOTECHNIK 35
OMEGA ENGINEERING INC. 20
ONDRIVES.US CORP 100
ORIENTAL MOTOR 89
PERFORMANCE MOTION DEVICES 12
PI (PHYSIK INSTRUMENTS) LP 65
PIVOT POINT, INC. 49
PRECISION PAPER TUBE COMPANY. 90
PROTO LABS, INC. 25, 56
PYRAMID INC. 57
REELL PRECISION MANUFACTURING 77
RITTAL CORP. 67
ROTOR CLIP CO. 19, 21
ROXTEC INC. 54
SAB NORTH AMERICA 96
SERVOMETER PRECISION MFG. GROUP LLC . 87
SEW EURODRIVE 1
SIEMENS INDUSTRY INC. 33
SMALLEY STEEL RING CO.. 27
SPIROL INTNL CORP 8
STEVEN ENGINEERING 81
SYMMCO. 76
TADIRAN 7
TDK-LAMBDA AMERICAS INC. 31
THE LEE COMPANY 52, 53
TOLOMATIC 61
TRIM-LOK INC. 44
TWO TECHNOLOGIES, INC. 76
VISUMATIC. 55
YASKAWA AMERICA INC.. 17
ZERO-MAX, INC. 43

In most cases, advertisements contained in Machine Design employment section indicate that the companies are equal opportunity employers. The Federal Civil Rights Act of 1964, and other laws, prohibit discrimination in employment based on race, color, religion, national origin, sex, or for any reason other than lack of professional qualification for the position being offered. It should be noted that employment advertisements in Machine Design are published for the readers convenience and, in no way, to the best of our knowledge, promote unlawful discrimination.

Classified

PRODUCTS/SERVICES

BRADFORD L. GOLDENSE | Contributing Technical Expert

Maximizing Revenues from the New-Product Pipeline

Does your company tightly control its manufacturing operations and work centers? If so, each work center is measured and the company knows exactly how much good and bad products the center produces. These figures are the center's "yield." Of course, companies aim for 100% positive yields from each center. And, products that have been manufactured for a long time often approach that ideal.

Now, let's apply the same basic concept of a center's yield to product development. There are series of centers that take new product concepts and bring them to market. But for these, 100% yields are not expected, nor would we wish them to be. Not every product brought to market is expected to be a financial success. If it were, innovation would dry up as companies would take no risks.

Many studies over the past five decades have found that somewhere between 35% and 55% of products are not financial successes. That figure can be as high as 90% in high-tech and consumer products. Those high failure rates create an opportunity to improve yield without risking the loss of innovation.

There are opportunities in most companies to get more revenues and profits from the product pipeline without increasing investment or headcount. Those opportunities have one common element—better decision making.

Too Few Ideas: If a company has too few ideas, management is forced to put them all into the pipeline because there are no others to choose from. If management wants to increase yield, they need to create more ideas. Better ideas increase the pipeline revenues and profits, even if the same number of products is ultimately released. There are just as many companies with too few ideas as there are that have too many ideas.

Too Many Ideas, Part 1: If a company has too many ideas, its challenge is relatively easier. Suppose 12 out of 21 ideas are approved for development. This seems reasonable. However, only eight ever get launched. Somehow, four of the 12 approved products died on the vine. This is a primary indicator that management is clogging the pipeline.

How and why did the four that died on the vine get approved in the first place? Was it because "no" decisions are hard to make? Was it because the business case presented for them was found later to be inaccurate? Was it because all business cases were accurate, but there was simply not enough capacity to do all 12? Was it because the sales organization reached capacity and couldn't launch any more new products in that time frame? Possibly it was a combination of these reasons, all of which are opportunities to improve the pipeline's yield.

There are always legitimate reasons for products dying on the vine. Perhaps a competitor launched a product superior to what your company was developing, and that necessitated stopping to redefine a better offering.

Too Many Ideas, Part 2: One reason cited in Part 1 was the lack of capacity. Those 12 products might have exceeded available capacity. If so, there is a secondary consideration whose logic lies in queuing theory. We have all driven through tollbooths on highways. What happens when there are too many cars on the road? All cars back up behind the tollbooth. The same is true for products in a pipeline. If a work center is overloaded, all products passing through it back up. And all will have a slower time-to-market and increased development cost, which lowers yield.

Yield Equates to Money: Suppose in our example that only three products achieved success. All the company's new product revenues and profits for that financial period stemmed from those three products. Hopefully the other five products that launched at least earned back their original development cost, but breaking even is not success. There was a huge opportunity cost to have developed better products that would earn back a multiple of their development costs.

Does your company know the yield of each work center in the product development pipeline? Does your company know when it approves one too many products into development, and the effect that has on other products in the pipeline? What can your company do, starting with the product concept, to improve its decisions for work centers?

The goal would be to realize four successful products instead of three. If it did, revenues and profits from new products could immediately jump on the order of 25% without changing anything else but the decisions. md

UPTIME TIME

– THE EXPERTS AGREE –

INTELLISENSE®

WINS THREE PRESTIGIOUS AWARDS
FROM LEADING INDUSTRY TRADE PUBLICATIONS

PNEUMATICS 2.0™ HAS ARRIVED

Introducing IntelliSense®, a one-of-a-kind technology platform that delivers real-time performance data on standard Bimba pneumatic devices for maximum uptime. Never before has such a wide range of industries been able to move from emergency repair to proactive maintenance, thus optimizing plant efficiency and production as a whole.

bimba.com/smarter